

The Energetics of Human Behavior

The Energetics of Human Behavior

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Cornell University Press

ITHACA, NEW YORK • 1948

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**Cornell University Press
London: Geoffrey Cumberlege
Oxford University Press**

**PRINTED IN THE UNITED STATES OF AMERICA BY THE
VAIL-BALLOU PRESS, INC., BINGHAMTON, NEW YORK**

A Prefatory Note

Dear Dr. Titchener:

It may seem strange to be writing to you across the years. Yet I know no better way to acknowledge an old debt and to fulfill a promise of long standing. I am in debt for your example of persistence in psychological inquiry, despite a multitude of cognate interests in such fields as collecting, anthropology, fiction writing, and music. My own outside interests have not been kept on a hobby plane as successfully as were yours. But I have tried to fulfill my promise to stay with psychology until something substantial was attained.

The pages which follow are a poor substitute for what I would have liked. When you helped turn my interest in behavior energetics away from the psychic constructs of Freud and into objective physiological experimentation, neither of us had any conception of what such work would involve. It meant years of poring over physiological and neurological researches, seeking for dynamic implications in essentially analytical work. It embraced the actual try-out on the intact human subject of every known variety of objective recording device. I did not know so much time would have to go into false leads.

Fortunately or unfortunately—that is beyond me to judge—the experimental procedures finally hit upon were so productive of new physiological data that I was en-

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couraged to make exploratory studies on a wide variety of psychological phenomena. It was always my intention to return to these areas for detailed "mop-up" work at a later date. But the pressure of the other interests urged me to move as rapidly as possible toward a general roughing-out of a point of view. I have always recognized that the researches published over the last decade are difficult to evaluate on any individual basis and that I was obligated to place them in a systematic context before going on to other things. That is what I have attempted to do here.

I count myself very fortunate that the Guggenheim Foundation granted the fellowship which made possible the completion of this book. I also wish to take the opportunity to acknowledge the various fellowships and grants-in-aid from the National Research Council, Rockefeller Foundation, Social Science Research Council, Northwestern University Research Council, and the Nutrition Laboratory of the Carnegie Institute of Washington that have supported the experimental program. Equally important is the inspiration and help received from my graduate students, including Drs. L. L. Giffin, C. I. Hovland, W. E. Kendall, L. Krasno, L. Onthank Mapes, C. R. Oldroyd, J. Pathman, H. Sargent, L. H. Sharp, R. M. Simpson, and E. K. Taylor.

I think, Dr. Titchener, your reaction to present-day experiments would be one of considerable disappointment, and so I dedicate this book to the psychologists of the future. May their work have more basic significance than the pebble picking that today clutters our professional journals.

Faithfully yours,

G. L. FREEMAN

September 1, 1948

The Freeman Farms

Watkins Glen, New York

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Systematic Behavior Theory

Rival Viewpoints. It is customary for writers on systematic behavior theory to begin their accounts by attacking rival viewpoints. In contrasting one's own views with those which have gone before, the new approach may gain clarity. This procedure has its dangers, however. The writer runs the risk of setting up straw men and of tilting at windmills. It is a matter of record that several discussions of behavior theory are better known for their telling criticism of rival viewpoints rather than for their own positive contribution.

The present account of why men behave as they do attempts to depart from customary procedure. In advancing the basic thesis—that *all behavior is an attempt to preserve organismic integrity by "homeostatic" restorations of equilibrium*—no detailed argument is made against configurationism, psychoanalysis, or the several varieties of behavioristic doctrine. Rather, this account opens with certain fundamental issues on which psychological theories are wont to part company. Some of these issues turn out to be matters of relative emphasis of parts within a larger whole; some arise from differences in level of description; others are resolved only by taking a stand on a strictly philosophical problem. After these issues have been discussed, the reader is invited to choose between behavioral descriptions made in terms of mentalistic concepts or strictly overt reac-

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tions and the present account, which seeks to establish full continuity between the overt reactions of the total organism and the covert self-regulatory processes of limited organ systems.

Why Theory? The layman, and many a professional psychologist as well, is inclined to regard discussions of behavior theory as unproductive and unscientific. To him, the fiery debates between members of rival "schools" are an unfortunate preoccupation with unsolvable philosophical problems, instead of with "the facts" of behavior and experience.

This dread of philosophy, so common among American psychologists, is often well warranted; certainly an understanding of what certain assumed postulates imply would cause many a psychologist to shift his factual position and modify his experimental procedures. Whether he realizes it or not, every researcher is proceeding from *some* theoretical point of view. This not only influences his interpretation of data, but actually determines the type and scope of "the facts" derived.

Psychology, in its present stage of development, presents a picture of much confusion. Theories differ in point of regard as well as in emphasized phenomena. A philosopher friend recently remarked that "whereas physicists, by adopting a common frame of reference, are able to understand the significance of work going on in each other's laboratories, in psychology only the completely muddled eclectic ¹

¹ The eclectic's position that "the scattered efforts of psychologists reveal an underlying unity of purpose" appears far too optimistic. One cannot condone the pose of indifference to the varied methods which produced the "facts" with which eclectic textbooks purport to deal. The desire of their authors to achieve catholicity and scope often results in a number of internally consistent topics; but these topics can be understood only as independent units and are not held together systematically, except as they all relate in some way to a living organism. Thus, when "sensation" is

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will grant a cognate importance to "mind gazing, complex lifting, opinion seeking, rat running and figure-ground manipulating." He felt, however, that the presence of controversy was itself a hopeful sign and that statements of rival hypotheses *in testable form* would eventually bring out the consistent over-all viewpoint that is characteristic of a mature science.

Neither psychology, nor any other science, can escape the need for theory construction. A theory exists to bridge gaps in knowledge. It serves to organize scattered phenomena into a consistent whole. It proposes questions of alleged relationship and opens these to experimental attack. In short, theory develops rather than impedes scientific progress.

There are three steps in theory construction. The first is the gathering and classifying of data; next comes an attempted abstraction of explanatory concepts; finally, the stage is reached where theory is sufficiently mature to imply testable propositions and to suggest relationships not yet actually observed. Experimentation now takes on the character of verification rather than mere discovery. Knowledge becomes more ordered as hypothetico-deductive methods replace the earlier stages of simple inductive reasoning.

Psychology's current emphasis on the third phase of theory construction is evidence of growing maturity. The

discussed, one inadvertently becomes a structuralist, and when "perception" is reached, the gestalt view comes to the fore. In explaining "learning," the behavioristic approach is usually adopted because of the great prominence of facts developed from this point of view, and "motivation" for the same reason tends to have a psychoanalytic cast. If it be answered that existing schools are not complete systems, but the outcomes of different gangs of engineers digging into the mound from different sides, there is still a question if their eventual "closing" on common ground is not retarded by emphasis on the products rather than the principles of research.

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hunches on which its hypothetico-deductive methods are now based did not come out of nowhere, but from previous observations. Its hypotheses, prior to verification, are propositions the experimenter holds as subject to doubt. Its researches involve a testing of hunches with more precise statements of alleged relations based on empirical data. As information is thus accumulated, the need for gap-filling theory tends to disappear. Variations in verbal descriptions given to the same relationship are recognized as such, and more fundamental differences are reconciled by adoption of the principle that is most consistent with the total fund of knowledge. Contrary to popular conception, accumulating evidence indicates that the more psychology becomes systematically minded and broadens its horizon to include methodological problems, the better becomes its understanding of the phenomena allocated to its sphere.

The Psychological Problem. What is the basic problem of psychology? Most psychologists will begin by agreeing that their problem is to understand the *behavior of the organism as a whole*. In further treatment, however, they tend to break on logical, and often illogical, lines. The skeptic, viewing a long history of earnest attempts at constructive order, may find only stylistic variations of the same old issues—the most fundamental of which are (a) the *mind-body relationship* and (b) the *part-whole relationship*. If this is actually the case, if the basic alternative “positions” were arrived at long ago, then we should first inquire which positions are most productive of significant empirical results and accord best with the interpretative principles of related sciences.²

² The author would insist on a closer relationship between the sciences than that held by Titchener (*Prolegomena*, Macmillan, 1930), namely

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From the above point of view, behavioristic theory has much to commend its use as a fundamental approach to the psychological problem. Atomistic and static as were its original constructs, it is essentially biological in linking consciousness to somatic action; and it is essentially scientific in creating a subject matter open to public inspection. Furthermore, the most complete understanding of the behavior of the organism-as-a-whole lies in extending objective description to the interaction of the bodily part-systems essentially involved in a total performance.

One of the basic weaknesses of behavioristic theory is an apparent inability to relate the motivated behavior of the total organism satisfactorily to the behavior of its more limited organ systems. An extension of Cannon's principle of homeostasis³ seems to fill the gap. This states that the organism is designed to react to change in a way calculated to restore disturbed equilibrium.

It will be the thesis of this book that objective descriptions of total neuromuscular homeostasis (in terms of the interaction of isolable overt and covert part-reaction systems)⁴ offer independent and direct measures of dynamic behavior wholes which in themselves will ultimately "out-field" the field theories of the gestaltist, psychoanalyst, and

that all have "a common desire to understand, predict, and control the world we live in." Nor can he agree with Bentley (*The Field of Psychology*, Appleton, 1929), who speaks of the "psychological sciences" as differing uniquely from the biological or physical sciences. It is realized, of course, that different methodological problems are faced in each science; but it seems that the interpretative principles of genotypic descriptions may and must be essentially the same irrespective of the superficial but irrelevant differences (phenotypes) between the multitudinous "facts" of specific areas.

³ Cf. G. L. Freeman, "The field of 'field' psychology," *Psychol. Rev.*, 47, 416-424, 1940.

⁴ W. F. Cannon, *The Wisdom of the Body*, Norton, 1933.

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other exponents of psychic energetics and phenomenological description. It is dedicated to those students of the psychological problem whose mature extensions of objective methodology are gradually refuting the cogent criticisms of early behavioristic constructs made by adherents of psychodynamic theory.

The Psychosomatic Relationship. Before proceeding to our application of the homeostatic principle to psychological problems, it is well to deal briefly with a traditional stumbling block to a thoroughgoing biological interpretation. The literature on the mind-body problem is tremendous, and need not be reviewed here. Since this problem is the touchstone of any behavior theory, we may mention some of the chief solutions of the psychosomatic relationship and adopt, as a basis for subsequent discussions, one which appears methodologically valid.

Of those dualistic positions that accept the reality of both psyche and soma without raising the problem of causation, the theory of interactionism is scientifically impossible. As Southland has pointed out, either a "mind twist" or a "brain spot" theory of behavior is equally feasible but the two will not mix. A better dualistic solution is that of psychophysical parallelism. It will not lead into methodological confusions, at least for a psychology that considers only the *psyche* or a physiology that considers only the *soma*. But the moment one attempts a precise matching of alleged parallelistic events, the fact that each set of descriptive constructs was built by independent methods makes a curious concoction. Aside from the difficulty of keeping two different clocks in perfect synchronization, the parallelistic position favors an unwise separation of psychological and biological science and encourages a futile type of physiological psychology which seeks to

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pull out from physiological research "bodily correlates" for discrete conscious states studied in another time and place.⁵

Two monistic solutions are possible. One is a straightforward idealism which disregards the body and all other aspects of the material world. The other is a straightforward materialism that disregards consciousness.

A compromise position of dualistic monism is reached in two varieties of double aspect theory, which treat both psychic and somatic events as different manifestations of the same fundamental energy system. These two variables of double aspect theory are *psychosomatic isomorphism* and *somatic determinism*.⁶ Current behavior study is anchored explicitly or implicitly to one or the other of these two positions.

The view of *somatic determinism* is espoused by behaviorists; it admits some relationship between psychic and somatic events but concentrates upon allegedly basic somatic processes. The view of *psychosomatic isomorphism* is espoused by gestaltists and psychoanalysts; it appears to attain better philosophical standing by sidestepping the problem of causation. This advantage, however, will not bear critical examination. In actual practice isomorphists often speak as if conscious "insight," "psychic tension," and "cognitive structure" are the cause of bodily actions.

⁵ Here we have only to point to the outcome of expressive studies in emotion. Much futile work was done on the assumption that every psychic emotional state has a resultant distinct bodily sign, as in anger and fear. Actually, these are situational meanings built upon functionally equivalent bodily reactions, and more precise differentia will be arrived at as easily by actual study of how the organism behaves in different situations as by appeal to how a person thinks he feels about them.

⁶ Our choice of this term rather than the more usual phrase, "epiphenomenalism," is dictated by the fact that the latter has so frequently been regarded as a form of materialistic monism that its retention in this context would be confusing.

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The fact that the static physiological constructs of early behaviorism appear unrelated to dynamic problems, furnishes the excuse for a flight into the freer realm of psychic energy constructs. Aware that modern science condones a monistic system, cognizant that the body cannot be left out of the picture entirely, and wishing to include or ignore it as occasion demands, gestaltists and psychoanalysts have hypostatized a *psychosomatic* organism. This viewpoint does not overcome either the philosophical or methodological difficulties of dualistic parallelism; but it often succeeds in obscuring the issue of causation. For instance, by adopting this view, statements are made which from the standpoint of external criticism are quite inharmonious. An example of this appears in a recent psychosomatic text.⁷ First we hear that "influencing psychological experience will directly change only the context of experience, and such changes should be expressed in psychological language," and then we learn that, "in many cases, we know more about the physiological aspects than we know of the psychological, and some of this material must be integrated into the work."

It is indeed a curious position which will permit one to employ psychic constructs freely in the explanation of total organismic behavior without reference to their bodily correlates at one time, only to turn to the latter aspects when no psychological construct appears to apply or when some physiological concomitant is more obvious. This is analogous to viewing the continuous flux of two visual fields, one of which (the somatic) requires a higher powered lens than the other (the psychic). The first field is ignored except as major changes occur and attention is given mainly to the lower powered field. This is like saying, "I will look at (and theorize about) the total organism from the psychic side of the coin as long as I please, and then continue my descriptive survey from the other side by simply changing from psychological to physiological language." The argument becomes especially vicious if the existence of a psychosomatic correlation at one point in a descriptive series is used to prove the scientific validity and essentially organismic nature of psychic constructs at another point. The mere fact that a psychoanalyst can exhibit a reduction of essential hypertension in his patient

⁷ J. F. Brown, *Psychodynamics of Abnormal Behavior*, McGraw-Hill, 1940

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following conscious insight into his mental conflicts does not prove that the antecedent organismic structure is as appropriately described in terms of id and superego interaction as in a strictly somatic context.⁸

Reduction in essential hypertension may be achieved by various methods, including psychotherapy, physiotherapy, and progressive relaxation. If psychoanalysis is to lay claim to essential unity with biological science on the grounds of occasional somatic cure, it would be equally feasible to construct a theory of the psychic life based on the effect of dunking. Such *post hoc* reasoning is one of the greatest sins against scientific method.

Treatment of the psychosome is not as clearly expressed by psychoanalysts as those adherents of gestalt theory who subscribe to the doctrine of isomorphism. According to Wertheimer, "any actual consciousness is in every case not only blindly coupled with its corresponding psychophysical process, but is akin to it in structural properties." Such isomorphism—a term meaning equality of form—assumes that "motion of atoms and molecules in the brain, are in their molar aspects, considered as processes in extension, identical." This theory proposed that we may infer the exact nature of correlated "macroscopic" brain processes from their conscious accompaniment directly and without resort to physiological methods of measurement. In other words, we may describe the fundamental nature of the other side of the coin by viewing only its conscious face. Admitting the legitimate criticism that the usual microscopic analysis ignores conscious wholes, we see at once that *isomorphism* challenges its chief rival, *somatic determinism*, to produce a better ex-

⁸ Too great importance cannot be laid upon Freud's contribution as a psychologist. While others of his generation were describing *what* men experience and learn, Freud was investigating the sources of energy behind these activities. Regardless of the assumptions of his theory (such as the psychosome and the unconscious, the libido and psychic causation), he demonstrated a number of propositions, chief of which was the reality of an interaction between an unlearned substratum and a learned superstructure in behavior. Many of his propositions are translatable to biological terms, while others appear appropriate only to the types of cases from which he derived his major theories. Cf. R. W. Sears, "Survey of objective studies of psychoanalytical concepts," *S.S.R.C. Bull.*, no. 51, 1944, and D. W. Orr, "Is there a homeostatic instinct?" *Psychoanal. Quart.*, 11, 312, 1942.

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planation of the conscious events (which somatic determinism regards as epiphenomena or shadows) than phenomenal description can provide for the correlated bodily features.

The most distressing thing about isomorphic doctrine is its verbal seductiveness in discouragement of psycho-physical attack. This position is achieved in several ways: first, by an unwarranted assumption that the phenomenal consciousness is adequate to total behavioral description; second, by the justified criticism that static isolating techniques of traditional physiology are ill adapted to the study of total behavior properties; and third, by the deceptive logic that such inadequacy in physiology permits one to pass from phenomenal to physical field-force analogy without further study of the biological organism. Whether it was intentional or not, these arguments have confounded many believers in somatic determinism and discouraged application of physiological methods to the more dynamic aspects of total response. But this is not half as serious as the influence that isomorphic doctrine has had on new recruits in psychology. In many of them it encourages a growing disregard for the body as body and for all physiological facts and methods which might ultimately contribute to a better understanding of total behavior. The glib talk of brain dynamics based exclusively on phenomenological reports covers a very superficial understanding. There is no escape from the fact that the most ardent exponents of isomorphism and psychodynamics know the least about the body, anatomically or physiologically, microscopically or macroscopically, dead or alive.

We will not cumber our main thesis with further discussion of the relative merits of the two opposed views of the mind-body relationship. A more detailed critique of isomorphism and a defense of somatic determinism ap-

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pears in Appendix I. Here we shall content ourselves with the statement that somatic determinism is a philosophical view consistent with behavioristic theory, and that its adoption implies the availability of objective methods for attacking phenomena usually recognized by their conscious aspects.⁹ If we are going to contend that consciously "directed" behavior acts to restore physiological equilibrium, we must expect to measure what bodily processes were disturbed and what bodily reactions were equilibrating. This leads at once to study of what is known concerning the relation of bodily processes to activity designated as "mental." The specific problems involved in this relationship are best approached in their historical context.

Motor Theories of Mental Activity. The success of objective behavior study is inseparably linked with an ability to record the significant motor processes going on in the intact organism when it engages in performances usually identified by conscious accompaniments, as in emotion, perception, and thought. Strictly speaking, there has never been a "system" of motor psychology. Rather it has been a working hypothesis of long standing that all conscious

⁹ H. A. Murray (*Explorations in Personality*, Oxford Univ. Press, 1938) has contended that such methods deal only with peripheral events, whereas the use of conscious meanings of behavior makes one a "centralist." This is, in our opinion, bad semantics. The terms "peripheralist" and "centralist" properly refer to adherents of peripheral or central control in behavior processes. A behaviorist can be either without giving special significance to conscious phenomena. The proper dichotomy for Murray would seem to be objectivist and subjectivist or observationist and constructivist. Reading between lines, it appears that Murray (and also Rorschach and Freud) is not so much concerned with subjective "mental" phenomena as in going behind observable behavior, setting up "as if" explanatory constructs and putting them to test. In this context, Murray levels a telling criticism against typical behavioristic doctrine. The importance of data is not limited by how it is collected, but also involves the manner of its interpretation.

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events have overt and covert motor accompaniments and that these are a necessary condition.

Description of the motor concomitants of consciousness has aided in the prediction and control of performance, and this has encouraged the abandonment of the psychic indices of behavior. The trend began with Bain, who emphasized the importance of visceral and kinesthetic excitation in the mental life. Motor psychology is found also in Darwin's treatise on expression of emotion; its first formalized statement appears with Féré, James, and Ribot, all of whom gave a psychomotor as opposed to a strictly mental description of psychological activity.

Ribot represented a fusion of two streams of thought, the total personality approach of his great psychiatric teacher, Charcot, and the mechanistic physiological psychology of Hartley and Cabanis. He asserted that even the creative imagination of artists and scholars is essentially motor. He proceeded one step beyond James and Lange in noting the mutual interaction of peripheral and central processes in the total response, emotion. Following suggestions implicit in Charcot's work on motor lapses in hysteria, he was also foremost in positing body physiology and brain disease as the basis for psychotic disorder; moreover, his desire for an empirical psychology of the higher mental processes led him to a study of the muscular accompaniments of conscious states. With Planchetti movement analyzers and his own keen vision of minimal movements made by persons during solution of "cognitive problems," he obtained the data which is the basis for his celebrated doctrine of attention. For Ribot, there were three types of motor response to the sensory stimulus with which they were associated; circulatory, postural, and sense-organ adjustment. Whether these adjustments are induced auto-

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matically by the stimulus or precede it as a "set" response aroused by some antecedent stimulus, Ribot did not make clear, but his contemporary, Féré, laid the groundwork for both possibilities.

Féré, another student of Charcot, conducted an experiment demonstrating that performance (squeezing a dynamometer) was automatically reinforced by music. From this he argued that a change in sensory stimulation is accompanied by a corresponding change in muscular tension; conversely increments in motor activity were said to reinforce sensory excitation. This doctrine of reciprocal effect is known as *dynamogenesis*.¹⁰ Féré, then, recognized that the function of stimuli is to liberate energy within the organism. Such transformations, expressed by increments in muscular tension, are caused even by apparently irrelevant stimuli. His theory led him to seek better measures of the neuromuscular aspects of total behavior previously identified only by consciousness. One of his discoveries was the psychogalvanic reflex, probably the best general index of amount of total neuromuscular activity that we have today. He also devised the first ergograph for measuring the amount of motor activity expended during prolonged work. Both Ribot and Féré showed keen insight in positing that motor processes are a necessary condition for consciousness but are not to be identified with it. While they tended to support an ideomotor theory which states

¹⁰ Other French psychologists of this period were much influenced by the psychomotor position. Even Bergstrom, an avowed vitalist, wrote: "Perception is primarily an act of consciousness conditioned by the body's motor set toward objects. . . . Anything that does not release an action is eliminated." His pupil, Finnbogason, wrote a motor account of sympathy, and Carpentier credited all conscious states with idea-motor tendencies. Dewey's critique of reflex concept (1896) is also based upon the principle of dynamogenesis.

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that any conscious idea always has movement accompaniments, they spoke of the "subjective impressions of movement" as something different from the idea itself.

In America, motor psychology found its earliest exponent in William James, who frequently appealed to the motor accompaniments of conscious states to emphasize his concept of the active organism. This is apparent in his theory of the emotional consciousness as due to backlash excitation from mass bodily reactions aroused by stimulation. The trend toward a motor conception of mental activity was given more exact expression in Münsterberg's "actionistic" psychology. Münsterberg believed that stimulation of a sense organ leads to a reflex motor response, and that consciousness arises in the passage of the neural impulse from sensory to motor regions. The vividness of experience is therefore associated with the intensity of the motor discharge. The more often the motor pathway is excited the greater the degree of consciousness. The fact that reflexes and habits (which have few conscious components) appear also to have open motor pathways is an embarrassment to this theory; yet it is the basis of all subsequent accounts of consciousness as based upon the postulate of the completed reflex arc. Critics of Münsterberg, such as Montague and White,¹¹ could only point out the negative instances, having no theory to explain why checking of a motor discharge increases the conscious state. At this point, Washburn¹² entered with her carefully formulated doctrine

¹¹ Montague, a philosopher, believes that the degree of consciousness is in inverse value to the openness of the sensory-motor pathway of the cortex, and White, a psychoanalyst, writes: "Consciousness arises only under conditions of conflict, conditions of great complexity, of increased resistance as compared with the facile reaction along the reflex path."

¹² Washburn's *Movement and Mental Imagery* (1914) was a classic in

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that consciousness accomplished a certain ratio of inhibition to excitation in the motor discharge. She says, "The facts of habit argue that consciousness accompanies interruption of response, and the facts of attention argue it is absent of interruption if complete." While her hypothesis cleverly reconciles the opposed views of Münsterberg and Montague, and sounds superficially like Sherrington's excitation-inhibition ratios of the spinal cord, it has no solid ground beneath it. How does the brain make checking of motor discharge a condition of consciousness; or do we have cord-consciousness as well, where there are many excitation-inhibition ratios? How may we know empirically that a movement is made tentatively and not completely? If one wishes to develop an inhibition-excitation hypothesis of consciousness, it would be more reasonable to suggest that inhibitory activity of the frontal lobes acts constantly to check the excitatory motor discharges of sensory stimulation, but that certain acts (as the reflexes) are of too low threshold for their weak stimulation effects to receive inhibitory check while very intense centripetal excitations (as in mass emotional discharge) are too much for the frontal inhibitions to nullify.

It seems more probable that the highest degree of consciousness accompanies a range of motor activity somewhere between the extremes of hypoexcitability and hyperexcitability. This idea is not readily handled by a

a day when American psychology was all but lost in mental statics. The early American functionalists (Dewey and Judd) all placed emphasis on the motor aspects of behavior, but the cause and effect relation between mind and body implicit in James sets them somewhat apart. To the extent that they deal with the response aspects of behavior as processes rather than stimuli, functional psychology has much in common with motor psychology.

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theory that appeals to the ratio of central excitatory and inhibitory processes. It has been suggested¹³ instead that the vigilance of the higher brain centers is mainly a function of amount of peripherally supported excitation. Such a theory draws its support from experiments showing motor accompaniments of consciousness. There is good experimental evidence for muscular tension influencing conscious phenomena,¹⁴ but none of the work may be considered crucial.

The question of temporal sequence or cause and effect relation between motor processes and consciousness is at present beyond the realm of experimental attack. The student of psychology, however, is satisfied with the demonstration of *some* connection between performances that are usually identified by consciousness and motor processes. He sees primarily in this relationship a reason to believe that refined objective methods will ultimately be adequate to all the problems of organismic action. He does not regard motor concomitants as identical with conscious introspection; he sees in them simply a more scientifically fruitful method of attacking those psychological problems that have

¹³ R. M. Simpson (81, 135) has shown that induced tension reduces sensory thresholds and Jacobsen and Cohen (94) and Lindley (16) have indicated likewise. Max has shown motor accompaniments or "finger dreaming" in deaf mutes; Jacobsen (94) and Shaw (129) have reported motor accompaniments for imagination. For an annotated bibliography of studies relating to motor theory, cf. (46). (Numbers in parenthesis are to full references in Appendix II.)

¹⁴ Watson was interested in the study of bodily parts and gave many pages to physiological and anatomical data as a basis for behavior study, but such neo-behaviorists as Skinner have discarded the earlier physiological orientation and are proceeding on the assumption that one can adequately understand total behavior without reference to the activity of bodily *parts*. It is doubtful if behaviorism gains anything by breaking with physiology. On some of the difficulties inherent in Skinner's position, cf. R. B. Loucks, *Psychol. Rev.*, 48, 105-128, 1941.

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been approached more or less exclusively from the phenomenological point of view.

The Part-Whole Relationship. Whether the psychologist chooses the path of phenomenology or eschews a survey of consciousness for its own sake, his own work will be influenced by empirical observations made from the opposite point of view. We need not consider especially the influence of objective behavioral method upon the phenomenology of gestaltists; in general, their qualitative observations have been made more precise and quantitative, and they have even come to use certain aspects of bodily action, such as direction and extent of locomotion, as criteria of the operations of phenomenal processes (insight) and psychic constructs (valence). The impact of gestalt psychology upon behaviorism has been much more telling and negative. Built originally on the facts and principles of an atomistic neurophysiology, objective behavior study has tended to investigate mainly the relations between the overt focal parts of a total reaction pattern and some striking aspect of the stimulus field. Such S-R analysis, of which the early studies of conditioning are typical, appear on the surface to justify gestalt psychology's major criticism, namely, that objective behavior study adopted the part analysis of traditional physiology and hence produced little information concerning the properties of dynamic wholes.

Behaviorists may well admit the criticism that, in the main, theirs has been a static analysis of part-reactions. But they need not be forced into a position that will deny to their methods, individually and together, the possibility of yielding total bodily descriptions. Hints of a motor type of macroscopic study have appeared in psychology since the time of Ribot.

Our immediate concern is with the place of part and

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whole analysis in the scientific study of the organism. Both are important. This section might be titled equally well "macroscopic and microscopic analysis" or "static and dynamic description," for part analysis is microscopic analysis and its products are relatively static; conversely, wholistic description deals with the dynamic macroscopic properties.

A source of contention can be removed at once. The gestalt psychologists, who are supposedly occupied with dynamic properties of macroscopic wholes, now admit the reality and even the importance of microscopic part description.¹⁵ On the other hand, it would be the grossest misconstruction to assume that behaviorists, because of their preoccupation with isolating microscopic techniques, are totally unaware of the problems of the dynamic whole.¹⁶ This does not mean, of course, that either group is content to assign the alternative problem to the other.

¹⁵ On this point we have the statement of Lewin that "it took psychology many steps before it was discovered that a dynamic whole has properties which are different from the properties of their parts or from the sum of their parts. Even relatively recently [in the early gestalt psychology] the statement was frequently made that the whole is more than the sum of its parts. Today such a formulation can be considered hardly adequate. The whole is not more than the sum of its parts, but it has different properties. The statement should be: 'The whole is different from the sum of its parts.' In other words, there does not exist a superiority of value of the whole. Both the whole and the parts are equally real. On the other hand, the whole has definite properties of its own. This statement has lost all its magic halo and has become a simple fact of science, since it was discovered that this holds also for physical parts of wholes" (*Am. J. Sociol.*, 44, 885, 1939).

¹⁶ Even Watson, who is usually thought of as the arch isolating-analyzer of behavior study, appears to admit the reality of the whole. He says (*Psychology*, 1919, page 11): "In psychology [as in physiology] our study is sometimes concerned with simple responses, sometimes with behavior in which several complex responses take place simultaneously . . . and are integrated as a group act. . . ."

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Levels of Description. We are now in a position to see that there is a more fundamental difference between behavioristic and phenomenological methods than their divergent views on the psychosomatic relationship or the part-whole problem. This difference is their level of description. Only the naive will think that controversy is settled by letting the gestalt group do the macroscopic analysis, the behaviorists the microscopic, and then fitting both types together, to the glory of psychology and the contentment of all concerned. With their primary interest centered in conscious phenomena, the gestaltist's descriptions of total behavior (in terms of psychic tensions and insight) do not satisfy the objective behaviorist; and the paucity of macroscopic physiological description is at variance with the needs of students of psychodynamics.

This issue of level of description is not easily resolved. Since individual minds differ in their demands, various levels of explanation inevitably exist. A familiar word satisfies one while a complex analysis is required by others. The most obvious distinction which can be made between levels of description or explanation¹⁷ is the one which

¹⁷ The relationship between description and explanation in science is one of such intimacy that seldom may the two be distinguished. In a strict sense description means an account of the perceptual qualities or characteristics of objects or events, and as such is contrasted with explanation which usually seeks to account for what is perceptible by means of factors and processes which are not open to immediate observation. By this definition, the realm of description is limited to the realm of immediate experience, for beyond them we avail ourselves of the generalizations and interpretations of explanations (cf. E. B. Titchener, *Amer. J. Psychol.*, 23, 115-182, 1912). Actually what we do commonly call description isn't as simple a matter as some would believe. We claim we see bees gathering honey, a storm approaching, but we shall be less ready to maintain that we simply and literally see these things unaided by any theory if we remember how comparatively recently in human history have these "explanations" become "descriptions" of what we see.

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holds between popular and scientific writing. The difference between these two levels is largely one of purpose and persistence. Popular interest is given to immediate relations and to an ignoring of remote consequences and antecedents. Scientific explanation varies from what has been called phenotypic classification, in which a multitude of things is replaced by a small number of groups, to genotypic description, in which a fact is explained by showing it in harmony with some general hypothesis or the postulates of a system. Current practice favors some type of genotypic theory, but here again, since nature and our insufficient knowledge have made an indeterminate number of systems possible, various *orders of explanation* may be permitted. By "order" is meant simply an explanation or description of a phenomenon with reference to any one of a number of explanatory systems. A given behavioral phenomenon may thus have several "genotypic" explanations in its relations to the axioms of different construct systems. It can, for example, be explained in terms of its conscious significance (or phenomenal meaning), its overt manifestations, or its covert physiological mechanisms.

The explanation which is considered "best" in science is that which most simply and adequately explains the facts of a given field and which is related by common axioms to the largest body of organized knowledge. Because of common goals, methods, and background, scientific systems are properly interlocking. Thus the axioms of chemistry tend to be found in the theorems of physics, and the postulates of biology are grounded in the theorems of chemistry. The systems of various fields of scientific work tend to cohere together in their construct relationships. However, especially in a new field of science, where facts are few and possible genotypic viewpoints many, a number of poorly ar-

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ticated alternative systems are to be found. It is the task of a young science such as psychology to select that level and order of description which seems most fruitful in relating behavioral phenomena with one another and with the facts and axioms of other sciences.

We believe that a total behavioral description can best be achieved by developing our knowledge of the *interaction* of part processes. These part processes have both covert and overt manifestations. These individual descriptions are closely related to the microscopic part analysis of physiology; their dynamic interaction, in addition, appears to hold promise of a more complete and satisfactory representation of macroscopic behavior totals than does psychical description.

Behavioral Description. Concerning the need for a macroscopic description of the organism's behavior and the inadequacy of existing microscopic physiology to the problem, there is little argument, Köhler¹⁸ has rightly pointed out that "we are seldom justified in considering the processes and states of larger systems as though they were mere aggregates of microscopic events." Goldstein¹⁹ has emphasized the reality of both microscopic and macroscopic properties and has shown in his own work that reflex mechanisms examined by isolating techniques exhibit in combination a dynamic interdependence wherein the identities of simple stimulus-response relations are entirely lost. The difference in the positions of these two men lies in the fact that Goldstein, as a biologist, makes considerable use of microscopic descriptions of behavior. When Köhler approaches the macroscopic problem, however, he dispenses with the biological methods and constructs and relies al-

¹⁸ W. Köhler, *Dynamics in Psychology*, Liveright, 1941.

¹⁹ K. Goldstein, *The Organism*, American Book Co., 1939.

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most solely upon hypothecated connections between phenomenal wholes and alleged biological wholes. Kohler seems to imply that there are some things (such as the color blue) we can never fully describe in anything but phenomenal terms. But this would not necessarily argue for the ultimate retention of phenomenology as science. If such were the case, physics would still have its sunset rather than its wave lengths. Science, as contrasted with common sense, is a search for the less obvious determinants of phenomena. No one can survey the history of scientific thought without being impressed by the fact that the most immediate and obvious explanations of a phenomenon have only a superficial connection with it. Thus the alchemist's explanation of the growth of a plant in the earth as a simple transposition of one added element (water) into another (wood) was replaced by Lavoisier's less obvious explanation in terms of the interaction of various substances derived from the plant, water, earth, and air. Similarly, the early explanation of scholastic success in terms of the training derived from the classical languages was replaced by the less obvious explanation in terms of the selective power of an intrinsically difficult subject. Phenomenology supplies us with obvious descriptions of macroscopic wholes. Like sophisticated common sense, it deals with end-results and stresses obvious relations. It appears already to have accomplished a major purpose in making psychologists aware of the macroscopic problems of behavior study. We should now be ready to take the responsibility for attempting more refined macroscopic analysis.

Some phenomenologists admit the possibilities of macroscopic biological descriptions. Commenting on the physicist Eddington's statement that "the (microscopic) survey of

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space misses any world-features which are not located in minute compartments," Köhler says,²⁰

If the study of macroscopic states as such had ever become the outstanding occupation of physics, the scientific world would now be more clearly conscious of these functional peculiarities. In consequence of it an application of such knowledge to problems of biology might at present be a well established practice. We cannot take it for granted that the scale of relative significance in which the physicist sees his several problems and subjects will always agree with their evaluation for purposes of biology and psychology. For biology and psychology, macroscopic dynamic states seem to be of paramount importance.

Furthermore, Kohler mentions the fact that Cannon's investigations of biological "steady states" are indicative of what may be done with macroscopic biological description, and Brown²¹ says that the ultimate description of dynamic wholes will be in terms of physiological psychology. Neither of these writers, however, has considered the possibility of applying Cannon's macroscopic biological principle of homeostasis to higher behavior phenomena.

The difficulty of achieving macroscopic biological descriptions is no special argument for return to phenomenology. In fact, no great help is required from phenomenology to construct a truly macroscopic biology. Objective study of the macroscopic and microscopic aspects of behavior should go together. The former absurdity of combining microscopic biology and macroscopic phenomenology (so decried by Köhler) is readily apparent. It is our thesis that biology can handle the macroscopic problem with its own

²⁰ W. Kohler, *op. cit.*

²¹ J. F. Brown, *Psychodynamics of Abnormal Behavior*, McGraw-Hill, 1940.

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tools, and, as in physics, by a study of the interaction of microscopically revealed parts.

Dynamics and Behaviorism. It is thought in some quarters that behaviorism (including all the varieties of stimulus-response psychology) necessarily implies a static analysis of part-reactions. The reflex arc concept, frequently used in this type of behavioral description, is said to presuppose a conduction of impulses from specific sense organ receptors over definite and inherently restricted nervous pathways to specific motor effectors. The straw-man behaviorist is said to associate overt part-responses with their adequate stimuli, and to assume that total behavior is compounded out of these elementary units. But the physiological concept of integration implies more than a mere extrinsic gluing together of S-R units by association. Since the time of Sherrington, many experiments have shown that reaction arcs are dynamically interactive. There is also ample evidence that the responses excited by stimulation of an efferent nerve are greatly influenced by the pattern of pre-existing excitation in the nerve centers.²² Let the limb of the dog be extended rather than flexed, and the stimulus which first induced scratching movements will now cause running movements. Let the arm be contracted to a certain degree and the amplitude of an ensuing knee jerk will be lessened; but let the antecedent arm tension be further increased and knee jerk amplitude will now be increased. These scattered examples serve to indicate that physiologists are neither unaware of dynamic problems nor are their meth-

²² Illustrations are numerous: the Jendressik hand-gift experiment, the Bowditch and Warren knee-jerk demonstration, Sherrington's "reciprocal innervation and reflex figure," the response of a cortical point as a function of the direction of stimulus approach, etc. Cf. G. L. Freeman, *Physiological Psychology*, Van Nostrand, 1948.

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ods inadequate to cope with them, on simple levels at least.

Why, then, have behaviorists, who would extend objective biological methods and description to complicated learned reactions, tended to ignore the fact that stimulation effects are superposed upon activity already present within the organism and are influenced by that background? Why have they tended to deal in terms of the external aspects of behavior and neglected that most essential dimension of psychological study, the intervening *set* of the organism? ²³ The answer is that they no longer ignore the problem.

The various behavioristic treatments which have appeared in recent years do attempt to get at the dynamic aspects of total reaction in terms of intervening variables. But because the empirical data have been largely limited to specific overt reactions, these behavior theorists have not fully met the dynamic challenge presented by psychoanalysis and gestalt theory. Failure to utilize measures of covert as well as of overt reaction in psychological experiments has forced the operational definition of the effective determinants of response in terms of past reaction or results produced. Thus Hull's "excitatory tendency," Guthrie's "postural cues," and Tolman's "manipulanda" are defined largely by reference to the animal's past performance. We would agree with Lewin's insistence that the factors for the organism's present behavior must ultimately be defined and measured in terms of factors operating in the present,

²³ Both J. F. Dashiell and the author have emphasized the need for approaching the concept of set objectively, and have developed objective methods which may be employed in its attack. Cf. J. F. Dashiell, "A neglected dimension of psychological research," *Psychol. Rev.*, 47, 289-305, 1940; G. L. Freeman, "The problem of set," *Amer. J. Psychol.*, 52, 16-30, 1939.

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and we would contend that the study of covert as well as overt processes operating in a situation might render unnecessary the historical definition of dynamic constructs. Until such time as this is feasible, however, it would seem unwise to deny the value of historical analysis and of continuity hypotheses of learning.

A behavioristic statement of total reaction dynamics is best done by analogy. Man is an energy system functioning as does the automobile to change energy from one form to another. The automobile's total dynamic properties (such as self-propelled movement in space) are a function of internal energy transformations. Macroscopic phenomenological descriptions of the rates and types of movement capable of being executed by the automobile (as a whole) are of limited usefulness. They will not aid greatly in stopping the automobile, nor getting it started again if it breaks down. The lady driver who bought her car on the basis of its general zip (phenomenal description of a total property), and who learned a few simple controls to run it, is usually at a loss when a breakdown occurs. She has to call the mechanic, who, instead of listening to stories of "it once ran" and "it did this and then I did that," goes to work on the parts whose proper interaction produces the lost "total property" of motion. He checks the function of each part separately, carburetor, ignition, feed line, turns over the motor, and lo—the total property "motion" again emerges. The human organism acts similarly. Phenomenal descriptions of the dynamic properties of behavior wholes may be useful as signposts, but they do not get at the essential interpart operations. At best they teach us to recognize when the behavioral total is shifting; at worst, they explain these shifts by appeal to unsubstantiated and

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nonbiological entities. A dynamic biology can handle this problem ²⁴ in terms of microscopic part processes interacting to produce the homeostatic adjustments of the organism as a whole. The action of these parts is the sole basis for association, with processes simultaneously operative in the body mutually influenced and influencing.

Behaviorists will realize that the part processes of the physiologist have to be studied as they work together in the intact organism. Theirs is a new branch of biological science, with total behavior conceived as the interaction of bodily parts. This dynamic treatment implies no appeal to emotion, thought, and other phenomenal wholes as independent and causal entities. To this vigorous logic we now commit "psycho" physiology. On its ability to attain a more complete behavioral description in terms of objectively recordable processes rests the chance to omit the psyche from the psychosome and to comprehend the whole by study of interrelated parts.

Motor Processes and Reaction Dynamics. In a previous section, major attention was given to the correlation between motor processes and conscious states considered in their more static aspects. That these same motor processes may be adequate to the dynamic problems of behavior wholes was indicated in the work of such pioneers as Ribot and Féré. But the dominant interest in elements of the mind (and later of behavior) following the turn of the century obscured the dynamical interpretation. It remained for the

²⁴ Behaviorists should realize what this entails. Just as one must appreciate the principles of internal gas combustion, gear reduction, and friction loss before the total functioning automobile is made clear, so the psychophysicist needs to attain a thorough understanding of detailed structure and function which are only indirectly related to the properties of the total human machine.

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psychiatrist Kempf ²⁵ to sound the first word of this new macroscopic interest. Dissatisfied with the psychic energy constructs of Freudian theory, he worked for a behavioristic interpretation of personality adjustment. According to Kempf,

When the tissue needs of some part of the automatic apparatus are thwarted, . . . that is to say . . . not immediately supplied by "proficient" motor reaction, the postural tensions of that part increase in relation to those of other parts . . . and the flow of stimulation from it dominates the efferent flux and hence the overt behavior; [consequently,] when the individual gets set on a postural course, like the exalted, the persecuted, the paranoid, the melancholic, it is extremely difficult for external stimulation to break through the stereotyped patterns of autonomic excitation and cause appropriate reaction.

The interplay between autonomic and central nervous activity is not fully worked out by Kempf, but we do see a realization that the interaction of these part-systems aids in the maintenance of essential constant or steady states of organic equilibrium.

Adherents of psychic energy constructs tend to regard the motor reactions discussed herein as results rather than as contributing forces to the dynamic field situation. Their treatment seems to imply that movements are merely the indifferent overflow of psychic tensions, and not one of the interacting forces. But one needs only to consider the reaction of an experienced rat in a suddenly foodless maze to realize how inadequate this approach may become. Here we have forward locomotion resulting supposedly from the dynamic interaction of inner hunger "tension" and outer food "valence"; but the fact that it makes no difference

²⁵ E. Kempf, *The Autonomic Functions and the Personality*, Nerv. and Men. Dis. Monog., 1921.

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to the run whether food is actually present or not, whereas any break in movement continuities between starting and stopping box is markedly influential, suggests that the visual image-excitation associated with the food goal is a result as well as a condition of movement. "Motor" psychology can be written from the field-theoretical point of view, provided we recognize the organism as a relatively closed energy system, with the interaction of S-R circles bounded by the skin.

Methodology. The reader has probably been looking for some statement of methodology that will implement the declaration of *the adequacy of recordable motor processes to the study of reaction dynamics*. Considering the past achievements of behavioristic research, he may be very skeptical. For are not the overt reactions of the behaviorist often wrongly evaluated as "stimulus" and "response" and are they not also incomplete and myopic? In admitting these criticisms we must call attention, however, to an additional methodology. Not only should the obvious overt reactions be studied at the moment, but also the covert or implicit reactions which developed concurrently, thus forming the background of the overt response pattern. With suitable instrumentation the entire spread or pattern of energy mobilization and discharge can be surveyed. These extensions of behavioristic method give, theoretically, all the details necessary to reconstruct the mechanics of interacting parts in total behavior patterning. Then overt reactions, now isolated as in our diagram (Figure 1), may be related not by appeal to hypothesized psychic energy constructs or historical verification, but by empirically determined motor antecedents and consequents which are below the threshold of overt response. On the need for exploring this possibility before relapsing into the vagaries

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of psychodynamics, we would be insistent. As a working hypothesis it has scarcely been tried. Behaviorists themselves are still largely at the stage of recording a single aspect of overt response, such as the eyelid reaction; a few are now using a given reaction to interpret the interaction of two stimulus-aroused variables. If behavior study is to be completely adequate to dynamic problems, simultaneous recording of several concomitant responses will probably be necessary.

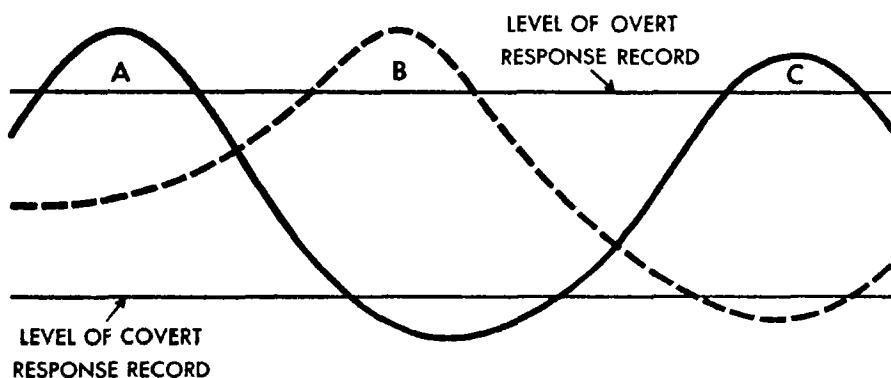


Figure 1. Covert reactions may link such apparently disconnected overt reactions as A and C, B may follow A in time, but have different antecedents.

Many psychologists have hesitated to use covert indices of behavior in their experiments, because of an understandable fear that the attachment of complicated recording instruments to human subjects alters the more natural situation and probably changes both covert and overt reactions. This difficulty may be met in one of two ways. If the recording equipment is very cumbersome and involved, it may be advisable to train thoroughly a few subjects in relaxing while trussed up—so that they “wear” instruments as other people do their glasses and clothes. If the recording equipment is more limited and it is desired to use less

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laboratory-wise subjects, every effort should be made to conceal the complicated details of equipment from the subject in another room or behind a screen. Only the electrodes or lead lines need be obvious, and an off-hand explanation given for their use which will not cause the subject to anticipate and worry about what he is showing on a concealed instrument. In this case, also, attention should be given to practicing the subject in relaxation with instruments attached. After several trials in which no harm comes to the subject as a result of wearing instruments, his original apprehension will largely disappear. Two experimenters are usually necessary for psychophysical research, one to handle the subject, the other to care for the recording equipment.

Advance in behavioral recording of the intact human organism has increased by leaps and bounds within the last decade. Besides learning more of the true significance of such well-known measures of covert activity as the galvanic skin response and the blood pressure, there has opened a whole new field of electrophysiology. The electroencephalogram and electromyograms are new tools whose aid to objective behavioral study may well be comparable to what the microscope did for anatomy. Today most of the people working with these new methods are too engrossed with technical detail to see their usefulness in extending total behavioral description to its essential covert aspects. These new methods show considerable promise, so much so that the empirical arguments of this account will be built almost entirely upon them. To those who contend that these methods will give no better description of total reaction dynamics than does the phenomenal report, time alone can provide the answer. After all, the psychical approach has had generations of

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work behind it, whereas the psychophysiological study of total behavior has had only a few years.

Prolegomena. Any theory is first grounded in logic and faith. No exception is made in the view to be developed herein, *that all behavior is homeostatic-regulatory and that the interaction of simultaneously recorded part-responses will comprehend the basic problems of total reaction dynamics.* The logic of this view comes from analogies of part-whole relationships in other fields. The faith is born of long study of the psychophysiology of higher order behavior. Throughout the exposition, no appeal is made to the phenomenal consciousness as a determinant of behavior. Instead of imputing determining tendencies to unmeasurable central conditions, it is held that central and peripheral changes are so inextricably tied together that *the central state may be understood by study of its peripheral accompaniments.* All behavior adjustments are thus viewed as physiologically equilibratory, neuromuscular in origin, and capable of objective measurement.

The view that *homeostasis* provides an essential integrating principle for tying psychology to physiology has been slow in developing. Much that is written in earlier accounts requires re-evaluation. The psychic isolationism of conscious states appears to be on the way out, and so does the pernicious dichotomy between organic and functional mental disorder. We want no monster, half-mind, half-body; nor do we wish to describe man in terms of extracorporeal wholes. On the other hand, lest the concept of homeostatic adjustment become an invitation to loose thinking, specific formulations must be made as testable as is possible. Leonardo da Vinci once said, "No inquiry that begins and ends in the intellect is worth treating seriously."

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The ultimate test of the behavior theory developed in this book, as of any other, will be the new facts, the empirical relationships, and the practical applications it is able to achieve.

The Organismic Energy System

The Organism as an Energy System. The term energy system means an arrangement of work capacities, potential or aroused, which forms a unified whole. The atom, the planets, and the man are all natural orders of matter whose actions constitute energy systems. As a living organism, man is that particular kind of an energy system whose behavior is not only an expender of aroused energy but also an attacher of new energy potential. This "open" type of system maintains a more or less constant level of energy transformation and hence does not run down or burn itself out by activity, as does a piece of coal.

To the old-line mechanist, the term energy has an unhealthy sound; but those who have shifted to the organismic point of view find nothing mystical in the concept. The fundamental problem of organismic biology is the organization and interaction of the bodily parts or mechanisms in various orders or systems of energy transformation. The cell is one system of energy, the digestive-circulatory apparatus is a higher order of energy system, and the total organism is an even more complicated one. The dynamics or total properties of these systems are just a higher type

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of mechanics, with discussions of energy change implying no appeal to vitalistic forces.¹

Measurement, however, is very essential, and this depends upon defining appropriately the *boundaries* within which energy changes will be studied. We cannot pursue with either convenience or profit the entire conservation of energy cycle of which a particular type of action is but a part. Rather we must confine ourselves to interchanges within a limited field of operation.

Energy transformation can, of course, be considered as occurring in any number of orders or systems—from atomic physics to the cosmos, from the single cell to the combined action of all living things. Parsimony and the shorthand of description require some principle for setting up boundaries within which measurement will be made; hence we rule that boundaries include only the environment immediately responsible for the activities which give the energy system in question its distinctive character. In practice this works out very neatly. The energetics of the iron molecule are studied in reference to its oxidative film surface. The boundary of the cellular energy system is its surrounding fluid media. When the behavior of the organism is taken as a whole, its basic field of energy transformation is *limited by the skin*. Failure to keep description within this boundary violates parsimony and destroys the continuity between psychology and organismic biology. “Psychic” and extra-corporeal energy constructs, being improperly “bounded,” fail to supply an adequate base for the measurement of behavior change.

¹ A detailed discussion of atomistic vs. organismic biology will be found in Appendix I. Attention is there given to clearing up the confusion that organismic and psychosomatic treatments of behavior are necessarily identical. Psychosomatic doctrine is organismic biology that involves special significance of mental processes.

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Lewin's² description of organismic action in terms of "psychological space" is a special instance of an ill-defined field of energy transformation. He pictures total behavior as arising from the conjoint action of internal forces (psychic tensions) and external agents (goal valences). This has obvious similarity to the gravitational pull of two objects whose mutual attraction constitutes a physical energy system. The differences in the analogy are not as convincing! A circle can indeed be drawn to define an energy system's field in physical space wherein two or more parts with similar properties (mass) generate a new total property (gravitational force) by virtue of their quantitative interactions. But if "psychological space" is to have similar meaning, one should not enclose essentially different objects (an irritable organism and an external stimulus) in a common field of operation, with locomotion the emergent property of the whole.

The effect of external stimulation is better represented by the excitation aroused in the organism via the specialized receptors, and its interaction with pre-existing bodily processes also occurs inside the skin.

Although Lewin does not do so, it is possible to put "psychological space" entirely within the organism, somewhat after the manner of Freud's regions of the Ego and the Id. But even here we must still ask if the constructs lend themselves to appropriate measurement. Consider the description of any instance of total behavior, such as the writing of these lines. The raw datum can be ordered by use of any number of constructs, physical, physiological, psychical, and ethical. Which leads to the most adequate prediction and control of the energy transformations involved? The physicist would probably yield to the physiologist here, provided only that the latter's constructs set the limits of action within the bounds of scientific parsimony and that they be metricized. These provisos the psychophysicist can fulfill, whereas the adherents of psychical energetics, Lewin and Freud, find it necessary to use extravagant and nonmetrical (topological) constructs.

² K. Lewin, *Principles of Topological Psychology*, McGraw-Hill, 1936. A critical report (G. L. Freeman, *Psychol. Rev.*, 47, 416-424, 1940) has pointed out that Kohler has gone further than Lewin in placing all stresses immediately responsible for behavior in the brain field. Yet Kohler's isomorphic doctrines are not stated in such a way as to stimulate psychology to the needed research.

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If the only energies that science recognizes are physical, it follows that persons who study that energy system known as the total organism should utilize physical methods of measurement.³ Historically this has been the line of progress in investigations of all orders of living energy structure. The energy transformations of the cell have been successfully measured by means of the biometer; when groups of cells are considered as forming an organ system, their dynamic interrelationships are measured by quantitative changes in the activity level of different parts. Numerous devices likewise exist for measuring the metabolic activity of the organism as a whole, or of its component parts. To be consonant with the study of energetics in other biological systems, these should be the methods used in the study of dynamic behavior wholes.

From our point of view, *total behavior dynamics is the study of an energy system undergoing change*. At any moment of observation we will have a pattern of biological energies with its roots both in the past and in the future. Cross-sectional analyses alone will not suffice. In order to indicate the operations of the functional total, a series of segmental observations needs to be made on a time continuum. The major variations in energy patterning so shown are the *realized* energy structures or organismic patterns,⁴ and from their study we reach an understanding of the potentials of the system as a whole. We get a fair idea of the limitations as well as the general extent of dynamic change;

³ For a critique of the misuse of topological (nonmetric) constructs in psychology cf. *Psychol. Rev.*, 51, 205, 1944.

⁴ The term "organismic pattern" was first used by Child to refer to the structure-functional order or integration which is constituted out of the potentialities of the protoplasmic substratum. Living protoplasm possesses various properties of reactions to its surrounding medium. Out of these interreactions are formed the organismic patterns. Change the character of the surrounding media or the potentialities of the protoplasms

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we find organic energies patterned very specifically at one time and relatively nonspecifically at another time; we see the disintegration of certain patterns, and the nascent development of others. In all this flux the problem of establishing a systematic order of study and description is not easily met. But certain similarities between human energetics and those found in more limited and stable systems of energy will serve as guideposts.

Energy Systems and Their Preservation. We live in a world composed of hierarchial *orders* of energy patterning, called total objects or systems, whose component elements, called *parts*, are constantly undergoing change and interaction, thus preserving the total structure. Organizations of lifeless matter such as the atom and molecule maintain a fairly constant energy structure for a long time by virtue of a relatively impermeable boundary between the dynamic forces within that structure and those outside forces of nature to which it is constantly exposed.⁵ Organizations of living matter, such as the cell, also maintain a fairly constant structure, but only by making up for the disintegration they suffer from reacting to outside excitants. Here the relatively permeable boundary of the system becomes an

and you change the organismic pattern. Organismic pattern is continuously changing, though after birth we see less obvious structural change. Therefore we tend to stress the functional, to the neglect of a sound biology of total behavior. Structure and function are entirely interdependent, the organism forming itself structurally by function, and functioning through its form. (Cf. G. L. Freeman, *Physiological Psychology*, Van Nostrand, 1948.)

⁵ Consider the tremendous outside force necessary to "crack" the atomic energy structure. A cyclotron must develop a speed of 50,000 revolutions per second in order for centrifugal force to develop sufficient strength to release the part materials (positive and negative charges) which have been preserved in dynamic equilibrium by a hitherto impenetrable boundary zone.

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advantage, for the energy materials within the cell are normally discharged by acts which bring about absorption of new energy materials from the surroundings. The original energy materials are constantly being eliminated and replaced, while the cell structure is held relatively constant.

As a biological energy system, man has a remarkable facility for maintaining his identity and for organizing himself and even the world about him to that end. This process of self-preservation is not to be ascribed to the operation of an intelligent mind, but is the natural result of a dynamic interaction between sensory and motor parts of the organic system. Thus an event, external or internal, which endangers organismic identity arouses the system to action and so becomes the indirect cause of its own remedy. This is akin to saying that the organism preserves its life through the operation of naturally constructed regulatory mechanisms aroused by conditions that need to be changed.⁶ The basic construct for ordering the behavior of an energy system is *homeostasis* or the maintenance of essential *constant states*. The latter term refers to a pattern or distribution of energies which the system is so constructed to restore when such states are disturbed. Cannon⁷ has pointed out many

⁶ In the end, of course, the disturbing conditions win out, and the organismic energy system undergoes dissolution. Stabilization of the organism's relation to its external environment might well be permanent were it not for the accumulating debt of internal senescence changes that do not come entirely from use. Death of the individual organism is in this sense a homeostatic function, making way for offspring that through evolutionary changes are more capable of preserving the identity of the species in a field of disturbing forces.

⁷ Pflüger is usually credited with being the first to call attention to automatic self-regulation in organisms. Hobhouse wrote, "Every organism is so built, whether by mechanical principles or not, that every deviation from the equilibrium point sets up a tendency to return to it." Claude Bernard spoke of the body tendency to keep the condition of the internal physiological environment constant. Bancroft developed a similar

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such self-preservative constants of the total organism, including the maintenance of body temperature and of a normal oxygen content within the blood stream. Similar processes aid in preserving the identity of inanimate systems.

Self-Preservation in Physical Energy Systems. Living tissue is not the only type of energy structure that maintains constant states. Inorganic manifolds frequently preserve their essential state because a disturbing factor indirectly creates a defense against itself. Consider the constant state of fluidity in a large body of water. This total property is preserved under adverse temperature conditions by the interaction of the total structure and its disequilibrating condition. Water is so structured that its density changes as it cools. At first, as surface water is chilled, it sinks to the bottom and warmer water rises from below. Hence the water cannot freeze, and lose fluidity, until the interchange of upper cold and lower warm water has thoroughly chilled the fluid to the bottom. Now we might expect the dynamic maintenance of fluidity to break down and the water to freeze solid. But the water molecule is so structured that as its freezing point is reached, it loses density and forms ice which floats on the warmer and more dense water molecules below. It is this ice, forming a protective surface sheet, that retards further freezing, which permits

principle that "a system tends to change so as to minimize an external disturbance." Haldane's classical monograph on *Respiration* presented the first systematic account of the self-preservative dynamics of an organismic constant state. But our greatest debt is to W. B. Cannon, whose masterly organization of accumulating evidence on steady states and their homeostatic maintenance (cf. *Wisdom of the Body*, Norton, 1932) has done most to eliminate the magic from descriptions of the process by which organisms keep alive.

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maintenance of fluidity in the remainder of the body of water.

Man has made use of practically all the known principles of inorganic reaction dynamics in the construction of machines which aid his own living. The governor is placed on an engine to maintain its constancy of speed; boats are built with a low center of gravity so that the more they tilt from the vertical, the more they tend to return to even keel; thermostats maintain constant temperatures inside the home and refrigerator because deviations from desired temperature are made to operate other mechanisms that will bring about readjustment.

If the equilibrium of inorganic energy states and of man-made machines is self-determined, this is doubly true for the living organism. Like the functioning physical system, all animals and plants are so structured that the difficulties they encounter help bring about the removal of these difficulties. But because the living system is in a constant state of flux continually taking in and giving off material, its self-preservative dynamics are more complicated and less simply understood. It was once a great mystery how the individual cells of any living tissue could preserve their anatomical and chemical structure while the material parts which composed them were continually being discarded and replaced. By the application of rigorous scientific methodology to the problem, the mystery has now disappeared. This fact should be a powerful reinforcement to those students of reaction dynamics who seek an essential continuity of explanation for the behavior of the total organism and that of other objects in the natural world.

Self-Preservation in Biological Energy Systems. The dynamics of self-preservation for the cell were dramatically

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demonstrated by Osterhout⁸ in connection with its potassium metabolism. It had been known previously that, in order to remain alive, the cell had to maintain a constant potassium concentration many times that of the blood or other surrounding media which are poorly supplied with potassium. At first glance this seems an exception to the laws of chemical dynamics, which suggest that potassium concentration inside and outside the cell vary together. Osterhout succeeded in fathoming this mystery precisely because he chose to regard the cell not as a marvelous epitomy of *élan vital*, not as summations of atomic parts, but as a physicochemical structure whose dynamic processes were essentially similar to those of nonliving material. In one of the shrewdest applications of hypothetico-deductive methods yet made to biological material, he reasoned as follows: Although the cell membrane cannot be permeated by potassium ions, if the ions trapped in alkaline compounds outside the cell were acted upon by its acid surface to form potassium salts, these might penetrate the external film and pass into the cell as whole molecules, even though the potassium concentration was already greater inside than outside the cell. There they would combine with the carbon dioxide, which is continually forming from the burning of sugar in metabolism, to form potassium hydrocarbonate. This soluble substance would be stably stored in high concentrations within the cell and released in combination with other outgoing materials that left the cell quantity in proportion to the amount taken in. The impouring of new potassium salts would continue to neutralize the acidity resulting from the burning of sugar regardless of internal potassium concentration,

⁸ Cf. W. B. Cannon's interpretation in *Wisdom of the Body*, Norton, 1940.

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and hence contribute to the preservation of the metabolic balance of the cell.

Such was Osterhout's hypothesis, and no laboratory findings could be cited against it. It remained, however, to be proved that the hypothesized potassium reaction dynamics actually took place. Here Osterhout resorted to the simplified conditions of an artificial "cell," where he could observe exactly what was going on. The "cell" consisted of a jar containing an oily substance of acid reaction to stimulate the cell wall. A glass tube suspended above the jar and protruding slightly into the oil film was filled with distilled water through which bubbled carbon dioxide gas to simulate the acid interior of the cell. A solution of potassium hydroxide was put outside the tube to simulate the potassium concentration outside the cell. If the hypothesis was a valid one, under these conditions a constant state of potassium hydroxide should be built up in the water inside the tube greater than and independent of the concentration of potassium outside. This is exactly what happened.

It is possible to go from the above demonstration of the reaction dynamics of the cell to those of the organism as a whole. Stimulation sets up reactions calculated to restore pre-existing equilibrium by discharging aroused excitation, and by so changing the organism's relation to the original irritant that it ceases to stimulate. Both in cells or in larger totals, the way living tissue maintains its essential stability is determined as naturally as are the constant states of inorganic materials, including man-made contrivances.

As we analyze various examples of self-preservation of constant states, it appears that the factor causing deviation from the optimum is sometimes within the organism or

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machine and sometimes originates on the outside. An overload acceleration in a steam engine and the gradual depletion of nutriment in the organism are inner conditions that endanger the constant states of these structures. The wind that tilts the boat and the heat that induces perspiration are outside conditions which endanger constant states.

We note also that every so-called constant state actually fluctuates with limits about a norm, and that, as with a pendulum, the greater the deviation, the greater the tendency to return to balance. Sometimes it appears as if the process of returning to the norm is initiated only after a certain threshold degree of change has occurred; this is seen in the case of the thermostatic regulation of room temperature through activation of an oil-burning furnace. More frequently the process of return is seen to be proportional throughout to the amount of change; this is the case of the thermostatic regulation of the water temperature in a car engine through continuous adjustment of the radiator shutters.

We have yet to inquire into the source of energies used to maintain constant states. Any self-preservative system is ever doing work. This requires energy. In the case of some inanimate structures such as the oscillating balance or rocking boat, the energy required is borrowed from the disturbance that causes the deviation. More frequently the energy is supplied from an extraneous source and requires tending, as when we put oil in the thermostatically regulated furnace. Living organisms have no tender—no external engineer. And while to some extent they borrow energy from the outside stimulus that originally caused the disturbance, organisms invariably react with more energy than acts upon them. Being only relatively closed systems, they lose energy in every reaction. This condition requires

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that organisms develop and maintain their own power plants. Unless they could store energy from the fuel supplies found in the surrounding media, they could not carry on re-equilibrating behavior to stimulus displacements, much less take care of necessary repair work in the reactive tissues. In other words, no complex organism could perform self-preservative functions as an autonomous machine without a specialized power plant interacting with its response system.

The Organism as a Constituted Unity. Some energy systems, such as the atom, are found in a highly organized state which changes little in time; some, such as man-made machines, have been constituted out of the interaction of other systems of energy. The organism is a system of energy which presents both these features. Although starting as a single cell and preserving a general identity throughout life, its more specific structuro-functional patterns are developed or constituted rather than preformed.

The fascinating study of experimental embryology has shown that organisms are what they are, structurally and functionally, because of the dynamical interaction of protoplasmic potentialities and the stimulating character of the surrounding field. From the time of conception the developing organism is reacting to external and internal disturbances and forming itself out of these reactions. Very soon differentiated structures emerge to care for specialized aspects of the general equilibratory process. As organisms become more highly developed ontogenetically and phylogenetically, the more part systems they possess and the more complicated is the process by which these parts act as an integrated unit. The physicochemical nature of the surrounding environment, internal as well as external, becomes of ever-increasing importance in determining the

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character of the total energy system. In meeting new disturbing conditions, part-systems already possessed by the organism interact to develop new total structures. Conflicting and locally determined reactions of these part-systems are often dangerous to the self-preservation of the total system. For example, the trapeze performer who responds to a local skin irritation by scratching may lose his balance and fall. Viewing the complexities that exist on the level of man, one marvels that he preserves any unity at all.

The best approach to the problem of how an organism composed of so many parts and part-systems reacts as a total is by way of experimental embryology. Early studies of embryological development indicated the priority of the whole. In the larvae of salamanders, Coghill ⁹ reported a lateral flexion on one side, followed immediately by flexion on the other side, these giving a sigmoid movement to the total organism that is fundamental in the later locomotions of swimming and walking. This occurred even before limb buds developed and the behavior of these parts arose in subjugation to the rhythmic "S" movement of the total organism. Only later did these parts gain a local autonomy; that is, a capacity to react more or less independently of the total system. These facts gave body to a simple formula which suggested that all behavior begins with the organism as a whole, and that reflexes appear as individuations from this total. If true, it would sweep away (as more or less irrelevant to the study of total behavior dynamics) all the painstaking analyses of isolated reflexes and their "laws" of integration. But the aesthetic attraction of such a universal formula was soon made untenable by other empirical findings. Work on the development of higher species such as

⁹ G. H. Coghill, *Anatomy and the Problem of Behavior*, Cambridge Univ. Press, 1929.

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the chick, guinea pig, and man indicates that the first response that can be elicited as the result of external disturbances is a relatively localized one of reflexlike nature. Such observations immediately return the problem of total reaction to the study of integrative action.

It is, of course, easy to say that development of organismic pattern proceeds in both directions—by individuation from larger wholes to more limited ones, and by integration from limited wholes to larger ones. Yet this provides little methodological basis for the study of behavior wholes of the adult human organism—it does not tell whether to approach them as wholes superior to the parts or as wholes built up of parts and understood in terms of the latter's interactions. Here our present knowledge of embryology would seem to support the position of proceeding with *parts in wholes*. As Carmichael¹⁰ has pointed out, it is difficult to make interspecies comparisons concerning "the zero of behavior" without scientific error; and the fact that in Coghill's salamanders the first total movement appeared before the limb buds had developed provides a condition fundamentally at variance with that of the human and mammalian fetus. Here there is some structural differentiation of parts before any stimulus-aroused behavior occurs, and that behavior has the characteristics of a local reflex response. This is likely to be rather disconcerting to the student of total reaction dynamics who had thought to dispense altogether with part-analysis. It suggests that while there are probably certain general physicochemical states that preserve the vegetative totality, the organic energy system had to achieve wholeness in its self-preservative reactions to an ever-expanding field of disruptive change, and that it does this by integrat-

¹⁰ L. Carmichael, *Genet. Psychol. Monog.*, 16, 339-491, 1934.

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ing and reintegrating the part-systems that individuate from a more fluid state. Very early embryologically, the organic energy system is a group of developing parts whose unity is preserved by interchanges within their common fluid matrix. The first part to be independent and locally excitable appears to be the muscle tissue; later neural control is established and these muscles come to react to internal stimulation, such as that derived from a proprioceptive complex; still later there is responsiveness to external stimuli acting upon exteroceptors. By this time the organism's field of potential stimulation has expanded so greatly that the problem of preserving constant states required by internal conditions has become more and more a problem of integrating and repatterning the action of part-systems and less and less the individuation of new parts from larger behavior wholes. The more specifically adaptive the behavior becomes, the less will there be of the total mass reaction. For students of the adult organism certainly it is fruitful to regard the total energy system as a *constituted unity*, to examine the parts which enter into the various forms it takes, and to study the dynamic relations of the parts involved for cues to the maintenance of total organismic identity.

The Organic Parts and Their Organization. Students of reaction dynamics will find here no detailed listing of the part-structures utilized by the living organism in effecting total behavior. These are more properly described in anatomy and physiology books. Here he should see that such part-structures are organized in an integrated pattern. Just as the metabolism of a single cell is a complex chain of chemical reactions, so is the process of total behavior in man's chain of interacting reactions of part on part.

We have already said that the organism, in order to pre-

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serve its essentially constant states, must maintain a power plant, the latent energies of which are adequate to support special apparatus for reacting to changes which threaten its identity. This powerhouse provides the first of two basic part-systems within the total organismic energy system. The other and superposed part-system is used for warding off external threats to organismic self-preservation and also for extracting from the external milieu the energies necessary for the continued existence of the body as a functioning unity.

The first organization of bodily parts is known as the digestive-circulatory system and the second as the neuromuscular system.¹¹ The two systems are complementary and mutually interactive. Since they tend to act together in the preservation of organismic identity, the key to the dynamics of total behavior is to be found more in the complicated energy exchanges going on within the body tissues than in the work of outside energies acting upon them. It has long been recognized that external changes, such as the air vibrations exciting the auditory nerve, serve mainly as "trigger" charges to release food energies already stored in the bodily tissue. Furthermore, the organismic energy system can become so structured that its neuromuscular response apparatus is not excited by external energy changes unrelated to its internal needs.

In order to gain an insight into the interactive properties of organic parts, it is essential to see the primacy of the digestive-circulatory system as a conditioner of total behavior. A set of basic tissues that require certain constancies of temperature, nutriment, etc., for their continued

¹¹ These part systems have been called "autonomic" and "proficient" by Kempf (*Nerv. and Ment. Dis. Monog.*, 1921, no. 28); they are sometimes spoken of as the tonic and phasic aspects of total response (54).

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functional existence are so structured as to set up internal excitation upon reaching states of excess or deficiency. This excitation has disruptive effects upon the parts of the superposed neuromuscular system, which, being displaced, initiates overt behavior calculated to produce alleviation of the basic tissue disturbance. These reaction dynamics may also work in reverse. An externally aroused excitation may disturb the neuromuscular system, whose reactions draw upon energies of the basic circulatory-digestive system and so disrupt their own constant states. As shown in Figure 2,

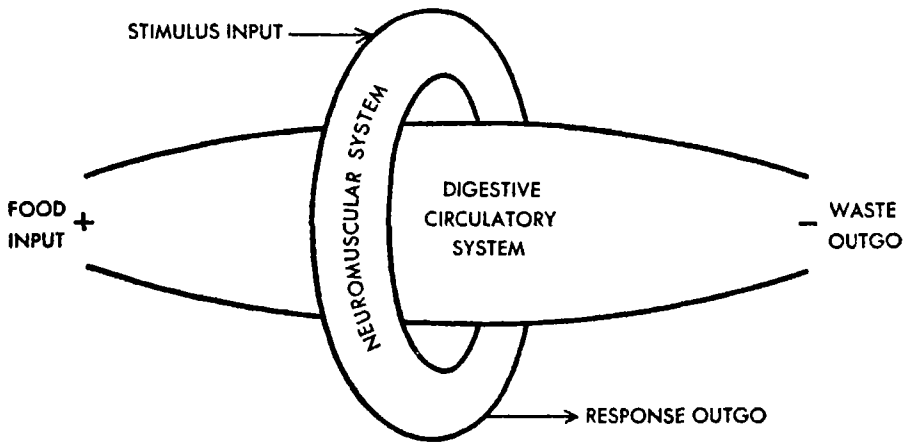


Figure 2. Interlocking part-reactions of the organismic energy system.

this process of mutual interaction of the two part-systems can go on quite circularly throughout life. In these self-regulating and self-perpetuating reaction dynamics, we see that food energies are changed by the digestive system into a concentrated type of fuel. This fuel, together with oxygen for burning it, is easily made available by the circulatory system to tissue of the neuromuscular system; *disrupting external stimuli touch off these energies* (catabolism), and response is made; this requires that new energies (anabolism) be built up through withdrawals from the stores of

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the digestive-circulatory system; as anabolism equals catabolism, a kind of "basal" equilibrium is again established. But before stores become seriously depleted there is sufficient disruption of the steady nutritive states to produce internal effects which excite the neuromuscular system to general spontaneous activity; among the potential reactions of this system are those leading to attainment of external stimulus energies (food, etc.) which will return the basic tissue conditions to their normal constant states. These essential maintenance operations are carried on by the interacting part-systems throughout life.

The Margin of Safety. No treatment of the organism's *maintenance* operations would be complete without some mention of the generous plan on which it is built. Just as the bridge designer adds a margin of safety to his structure by building it several times as strong as the estimated loads it will carry, so our bodies are organized to allow for overload in times of stress. It is a noteworthy fact that in the construction of the body most of the organic parts are paired. We do not actually need two lungs to breathe, two kidneys to remove waste products, or even two cerebral hemispheres to direct equilibratory responses of the total organism. Four-fifths of the thyroid gland can be removed without the appearance of deficiency symptoms, and the same is true for the pancreas, where only one-fifth is necessary to provide the normal insulin needs of the body. The organs of reproduction show a superabundant waste of tissue and activity in order to assure success of the primary function. There are many instances when the function of one organ in times of stress is assured by the assistance of others, and continuance of organismic identity is further protected by the internal mechanisms of self-repair. But the greatest of all assets, in higher organisms at least, is the

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tendency to develop and to maintain an external environment where threatening change can be kept at a minimum. Both in terms of its inherent structure and its adaptive responses, the organismic energy system is thus provided with a generous economy and a large margin of safety.

Organismic Energy Transformations. The energetics of total behavior pose two basic problems: one builds around the question of *energy sources*, the other around the nature of the *control mechanism* which directs the expression of energies which are aroused. On both, authorities have reached substantial agreement.

Studies showing that hunger contractions of the stomach coincide with periods of general neuromuscular activity have indicated the importance of the digestive-circulatory system as a source of energy; experimental removal and implantation of the several endocrine glands have contributed to our knowledge of more diffuse energizing phenomena—in which internal tissue “need” manifests itself mainly by raised metabolism and reactivity of the neuromuscular system.

In the matter of control mechanisms, it is fairly certain that the superposed neuromuscular system is supplied with a minimum of internal steer to the expression of aroused energies. This system is especially adapted for acquiring or avoiding new stimulus energies which are beneficial or harmful to the maintenance of essential constant states. The organismic energy system is always in action. It is either attempting to secure new energy sources or to control the expression of those already aroused. Study of the energetics of human behavior begins therefore with measurement of changes in the activity level of the essential part-systems. The fact that such records can be obtained in

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the intact organism makes possible the study of parts interacting to form wholes.

The Problem of Measurement. Measurement of the metabolic activity of a living cell or of groups of cells may be accomplished in various ways. Those most frequently used are heat production, gas analysis of expired air, and oxygen consumption. Calorimetry is considered the most direct measure of rate of energy transformation in biological systems. The cumbersome character of the recording equipment used in measuring heat production has not led to a ready acceptance. But since rate of oxygen consumption is proportional to amount of fuel burned, it is convenient to use this as the measure of metabolic activity of the organism-as-a-whole. So generally has this measure been applied that to many persons "metabolism" is synonymous with oxygen consumption, and no other index procedure is seriously considered. This is unfortunate since its relative insensitivity as a measure of the energy cost of neuromuscular work should encourage students of organismic energy transformation to develop other indirect means of assay. The fundamental difficulty with well-recognized measures of total metabolism is that there normally exists in the organism sufficient local energy reserves to effect adequate adjustments to displacing stimuli without occasioning an immediate increase in the general level of vital activity. The neuromuscular system is notable for its conservative use of the energy reserves of the digestive-circulatory system.¹² Consequently, many significant but

¹² Neurones burn fuel during work and replenish the supply from the blood stream at once. This energy exchange is very minute and probably occurs within the refractory period, during which the neurone is prevented from normal activity. A far greater quantitative exchange occurs when the muscles react. In fact, if there is any reflection of increased energy cost

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minute energy transformations occur which are but indefinitely reflected in conventional metabolic measurement.

To advance the study of organismic energy transformation beyond its gross and superficial stages, it will be necessary to divorce the term "metabolism" from its tradition-haloed meaning and rethink the problem from the ground up.

Metabolism Redefined. Energy as we meet it in the organism is produced by the processes of metabolism. Tissues use and give off more or less energy waste products according to the rate at which they are metabolizing. A high level of activity in a tissue means a high rate of metabolism. One tissue derives energy for its own operations by drawing directly or indirectly upon the products of metabolism of other tissues. The blood and the nerves work together in carrying out these effects. Besides containing the materials essential for metabolic activity of any tissue (oxygen and glycogen), the blood transports the products of metabolism from certain tissues (glands, etc.) to other tissues (muscles and nerves) where the chemical stimulus acts directly to increase the metabolic activity (or reaction level) of these tissues. The nerves convey the indirect effect of metabolic activity from one tissue to another. Thus increased activity (metabolism) in a muscle increases efferent excitation of the brain (via proprioceptors from this muscle), and this in turn stimulates some other muscle, gland, or nerve tissue to increased activity (metabolism). From this analysis it should follow that the most significant

during so-called mental or brain work it is likely due to associated muscle activity. Informed psychologists long ago gave up the pernicious dichotomy of mental and muscular work. The distinction between digging a ditch and solving a mathematical problem is only one of degree, especially with regard to energy cost. The nerves and muscles are involved in both types of work.

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aspects of the organic energy flux are not to be found in the consumption of food or oxygen but in the *use* which specific tissues make of these materials—in the patterning of energy transformations rather than the sum total effects occasioned by changing stimulation and need.

A bodily organ or tissue may function only within a limited range of activity; if the rate of metabolic exchange falls below or exceeds such limits, it dies. Thus the quanta of energy which can be mobilized in a total behavior pattern is defined by the upper metabolic limits or activity levels of all the tissues engaged in that total activity. The question as to the absolute limits of this total process is largely rhetorical. The only sure test that such limits have been reached would be the departure of essential constant states beyond the margin of safety, and this would mean death.

It is more fruitful to inquire concerning relative levels of energy mobilization than to talk in terms of theoretically absolute limits. If a person is more reactive in one situation than in another, or if under similar external change the activity level of certain tissues is greater at one time than another, we may conclude that he is operating on a higher "energy level." We are also at liberty to use any quantifiable and stable indicator of tissue activity as a measure of the energy transformation of that tissue or of fundamentally related tissues.

This unorthodoxy is not without reason and support. Not only do we need sensitive measures of total composite metabolism, but also we must seek devices that will indicate the relative activity level of the different part-systems which function within the total. This need becomes especially imperative when we recall that the understanding of reaction dynamics depends upon an ability to study the interac-

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tion of bodily parts during total behavior. Those two great systems, the digestive-circulatory and the neuromuscular, must certainly be represented by reactivity-metabolic measurements, and parts of these systems having special significance for particular situations must also be surveyed.

At first glance this seems a hopelessly unattainable program for the study of organismic energy transformation. We are reminded that measuring even the composite metabolism of the intact organism is no small methodological task. Of the various indicators of bodily change which can be used with the intact organism (blood pressure, respiration rate, sweating, electrical discharges of nerve and muscle tissue, etc.), little is known of their significance for the study of total reaction dynamics. Seldom is more than one of these indicators used concurrently during a study of total behavior, and seldom does the experimenter have any fundamental insight into the nature of the indicator he is using.¹³ But the more fundamental obstruction lies in the way the results are usually interpreted.

Significance of Bodily Activity Records. We may recall that practically all bodily measures are treated as instances of overt behavior; that is, they are traditionally studied in terms of their outer significance only. It is common to catalog bodily movements, indicating their differences in latency and extent (as between the "knee jerk" and the "psychogalvanic reflex")—that is, to treat them as types of responses. Even the covert behaviors of the muscles and

¹³ Psychophysicists in the past have been fadists; in their desire to obtain bodily correlates for consciously represented "states," they have attached first one gadget after another to protesting introspectors. Once it was fashionable to use the plethysmograph. Then there was an attempt to correlate different swings of the galvanometer with different emotions. Now we have a rush to electroencephalography, and much of the wrong type of work is again being done.

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glands (such as are revealed by action potential records and biochemical assay of the blood) are often forced into the same classificatory molds. Each type of response is studied as an end in itself rather than for the significance it may have for total reaction dynamics.

Occasionally do we find an investigator regarding a recordable motor process as indicative of metabolic changes in the tissues immediately responsible for the record and also of changes in functionally related tissues. Such was the case in Lombard's (103) classical use of the knee jerk amplitude to indicate relative degrees of neuromuscular activity under various central conditions of "attention." A similar usage appears in Luria's (105) studies of the motor concomitants of "mental conflicts." There is no need to invoke psychic constructs in these connections. The central and peripheral components of total behavior are so inextricably bound together that reactivity in peripheral muscle tissue reflects and helps determine reactivity of central neural tissue. Every record of changes in motor behavior is to some extent a record of central changes in the neuromuscular system of the digestive-circulatory system. One can get at the dynamic changes occurring within the central control mechanism by way of accompanying peripheral changes. We have only to ask, "What is the significance of this record for total reaction dynamics?" Then our experiments will be on the way to supplying answers to many questions which hamper the measurement of the complex energy transformations of the intact organism. We shall find certain bodily indicators more useful for composite (total) changes than others, and we shall come to attach special significance to certain behavioral records of part-system functioning. We shall arrange experimental situations designed to unbalance the organismic energy system,

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so that we may observe under controlled conditions the equilibratory processes involved. We shall study relatively unbalanced human energy systems and compare these with balanced (normal) systems in much the same way. In the words of Luria (103), whose treatment of this latter problem would closely parallel our own:

We turn in a new direction—replacing the study of symptoms by the investigation of the structure and dynamics of the processes of disorganization of human behavior. . . . [Here] we should on the one hand produce the central process of the disorganization of behavior; on the other hand we should try to reflect this process in some [peripheral] system accessible and suitable for examination. Motor function is such a systemic objectively reflected structure of hidden psychophysiological processes. . . . In this classification of our work—we are only very slightly interested in the motor activities of the subject *per se*. . . . In our investigations of these [motor activities] will serve us only as a path to the concealed [central] processes, only the systemic reflection of their structures.

Selection of Measuring Instruments. Two aspects of the problem of energy measurement are not made explicit in the previous discussion. One concerns the selection of those registerable tissue activities that will constitute the most significant indicators of total reaction dynamics; the other concerns the reliability of these measurement devices.

The study of organismic energy transformation requires an indicator which is *stable* enough to provide records having normative significance and which is sufficiently *sensitive* to express minimal changes in physiological reactivity. It is often thought that these two properties cannot be shared by the same indicator, and that the most sensitive measure is also the least reliable.

Changes in electrical skin resistance are a case in point;

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while recognized as very responsive to stimulation effects, inconsistencies in the use of the measure have been reported.¹⁴ Some physiologists have felt that such measures are so inconstant for a given individual as to carry no helpful reference to those relatively persistent internal conditions of basal metabolism. They have preferred instead a much cruder but apparently more reliable index of general reactivity—the oxygen consumption record of metabolic rate. Few comparative tests of these two types of measure have ever been made, and little attention has been given to the test-retest reliabilities of oxygen consumption records.

Once we accept the postulate that any measure of the excitation level of body tissues is an index of their rate of energy transformation, an empirical comparison of the efficacy of available measures is indicated. These potential indices of general metabolism are usually given the following order-of-merit ranking: calorimetry, oxygen consumption, total insensible weight loss, palmar skin resistance, blood pressure, and muscle tension. High correlation between the first three measures is generally recognized. But there is some question whether the last three measures are of the same order as the first three, particularly since such records are more intimately influenced by changes in some special tissue than by the total mass of energy transformations. Only the desire to secure an index more responsive to the metabolic changes associated with so-called “mental” work led to any detailed examination of these latter measures. A notable insensitivity of the usual meta-

¹⁴ Skin resistance level (and reflex [GSR] changes built thereon) is a function not only of the organism's state of reactivity, but also of the technique of measurement. Until investigators use similar measuring circuits, their data will not be directly comparable (24, 73).

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bolic measures to increased activity of the higher nervous centers has been reported by many investigators. Hence the search has shifted to more rapid-acting tissue activities whose apparently limited scope was once thought to preclude their use as an index of general metabolism. Such work has opened new vistas for the measurement of the energy transformations of the intact organisms.

The electrodermal resistance of the palm has shown great promise as an indicator of metabolic activity. Produced largely through sweat gland activity, these changes correlate with such grosser measures of energy transformation as weight loss (65) and oxygen consumption (68). The neural innervation of the sweat glands gives to palmar skin resistance measures a unique functional significance. This measure summates both sympathetic and parasympathetic effects (25), reflects increased tension in skeletal muscles, and is one of the first response mechanisms to show the effects of new stimulus demands. Like records of oxygen consumption, palmar resistance changes are little influenced by changes in room temperature and humidity (68). Within limits, it is more efficient in showing small increments in neuromuscular activity than is a concurrent record of oxygen consumption (64). These facts, together with a high test-retest reliability, commend the measure for use as a significant index of energy mobilization in the intact organism.

Activity measures of seemingly more limited significance than palmar skin resistance include changes in blood pressure, mechanical and electrical indices of skeletal muscle tension, electroencephalograms, and the overt motor reactions. The weakest point of certain of these measures is also their strongest; for, while action potentials from one group of skeletal muscles may not be symptomatic of

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the activity level of the entire musculature, the specificity of the record makes it useful in detecting changes in the *pattern* of energy transformation.

Derived Measures of Part-Reactions. If one is interested in the energy transformations of different part-reactions systems, he will need to use a combination of measures and derive this information by formulae. The recordable tissue activities often express changes initiated by several bodily parts; consequently a great deal of current work is concerned with the interrelations of various tissue activities by use of simultaneous recordings.

It is beyond the scope of this book to discuss tissue interrelations in any detail. We mention only the two distinct but interdependent control systems: (1) the neuromuscular system with direct "central" nervous control of the skeletal muscles, (2) the digestive-circulatory system with "parasympathetic" and "sympathetic" control of smooth muscles and glands. It has been found possible to express the relative activity of these systems by index numbers derived from standard scores of simultaneously recorded palmar skin resistance, blood pressure, and muscle action potentials (25, 53). These measures of part-reactions may be derived from the following equations:

Since blood pressure (BP) expresses sympathetic activity minus parasympathetic activity and palmar skin conductance (C) summates such activities, formulae for each part-activity are:

$$\text{Parasympathetic activity} = \frac{C - BP}{2}$$

$$\text{Sympathetic activity} = \frac{C + BP}{2}$$

And since potential changes (PC) in skeletal muscle summate centrally controlled activity with that induced indi-

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rectly as an autonomic "overflow" phenomenon, by formula:

$$\text{Central nervous system activity} = \text{PC} - \text{BP} - \frac{\text{C} + \text{BP}}{2}$$

The electroencephalogram provides another index of central nervous activity. There is considerable support for the theory that its spontaneous rhythms reflect the level of cortical excitation. High correlations have been reported between the frequency of the slow alpha rhythm and the subject's general metabolic level. There is also good qualitative evidence that conditions of intense alertness and extreme lethargy stand at two extremes in "blocking out" these regular brain waves. High metabolic activity in cortical tissue is presumably accompanied by no rhythmic action potentials; states of moderate excitation are probably correlated with high frequency-low amplitude potentials and states of moderate relaxation with slower frequencies and the beginnings of irregularity; states of very deep sleep are apparently accompanied by very slow random changes in electrical potential. With limited external stimulation, the recorded potential changes are largely determined by the humoral processes affecting the cortical cells (59) and by neural impulses arriving from lower centers. It would be very difficult to separate these excitatory effects. In one exploratory study, it was found that per cent time alpha in electroencephalograms rose and fell concomitantly with changes in palmar skin resistance and muscle action potentials (59). The importance of cardiovascular changes is also recognized (66). From what we now know, it would appear that the determinants of the electrical activity of the brain are both numerous and complex, and that no simple formula will permit its use as an index of the degree of arousal of the neuromuscular system.

THE ORGANISMIC ENERGY SYSTEM

From Limited to Total (Neuromuscular) Homeostasis. While technicalities of the preceding sections have taken us away from the over-all view of the organismic energy system, this final paragraph will serve both as reorientation and forecast. We have previously characterized the living organism as a system of energy capable of maintaining its identity for an indefinite time in the face of threatening change. We have indicated that the organs which comprise the digestive-circulatory system are engaged in limited maintenance operations necessary to preserve essential constant states, blood sugar, water balance, etc. We have seen that the superposed neuromuscular system first becomes involved in homeostatic operations only as internal demands, such as food or oxygen, require contact with or withdrawal from external energy sources. Later, due to a superabundance of potential but unmobilized bodily energies, the neuromuscular system is "alerted" for all varieties of external stimuli, reaction to which is less directly connected with the preservation of essential life constancies. It is the purpose of remaining chapters to show that such total behavior (a) follows a measurable course of equilibratory energy transformation in which the stimulus is made to cause its own remedy and (b) is related in all essential respects to the limited organ reactions which keep the body alive and maintain its identity. A causal connection presumably relates all levels of homeostatic adjustment. At the levels usually identified by the so-called "conscious" accompaniments of thought, however, we often tend to stress phenomena which have little to do with psychophysiological equilibrium. This is an unfortunate state of affairs. Except for psychology's past preoccupation with the products rather than the processes of energy

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transformation, the self-preservative function of every organismic act would be generally recognized and the concept of homeostasis would be widely accepted as the key organizing principle for total dynamic reactions.

The Homeostatic Response Curve

Equilibratory Energy Transformations. Before describing the major areas of behavior study in terms of neuromuscular homeostasis, the general characteristics of the process must be surveyed. This involves special experimental methods and special interpretive concepts. The present chapter analyzes results obtained when covert measures of total metabolic charge are recorded concurrently with overt response measures.

For purposes of study, the typical homeostatic response curve can be treated somewhat in isolation. The human subject is brought into the laboratory and “relaxed down” until a measure of basal tissue activities “levels off” to indicate the more persistent background conditions of quiet rest. From this *basic energy level* the subject is “displaced” by an external stimulus of controlled intensity and duration. The equilibratory sequence has three phases: (1) *mobilization*, wherein bodily energies are internally aroused to meet the stimulus-induced displacement; (2) *discharge*, wherein the aroused energies are externally expressed by overt response; and (3) *recovery*, wherein the organismic energy system returns toward its prestimulus condition.

Total energy transformation may be approached experi-

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mentally in any of three ways: (a) variations in response discharge to a standard stimulus produced by manipulation of the basic energy level; (b) gross quantitative changes in arousal, discharge, and recovery indices produced by varied stimulus displacement; (c) changes in overt behavior patterning or energy distribution under varying stimulus conditions.

The effect on overt response of alternations in basic energy level is the easiest approach to neuromuscular homeostasis. It requires no elaborate instrumentation, only some method for systematic variation of internal background conditions (as by induced muscular tension or drug intake). Contrawise, some indicator of basal tissue activity (such as the oxidative metabolism or the galvanic skin conductance measures described in Chapter II) is always required to study the gross features of equilibratory energy transformation under varied external stimulation. For the finer aspects of energy patterning, records are obtained of activity in focal and nonfocal muscles in the overt behavioral discharge.

Problems and results peculiar to each methodology are discussed in order. This, in turn, sets the stage for the operational definition of such constructs as are necessary to extend the homeostatic interpretation to all varieties of total behavior.

Background Energy Condition and Focal Response. Our analysis of response energetics begins with a type of psychological study not usually thought to involve energy assumptions. Everyone is familiar with the fact that when the internal condition of the organism is altered, overt response to a standard external stimulus is also affected. We shall see that such work implies a basic principle in equilibratory energy transformation, namely, *the focal response*

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discharge is always the product of stimulus-induced excitation and the background energy condition already present.

Early behavioristic doctrine missed the above principle entirely. Implications of the simple S-R formula led to an unfortunate conception of man as a congeries of reaction arcs—a complicated jumping-jack moved in prescribed ways by external stimulus controls. Later students attempted to patch up the original formula by inserting “continuing postural cues” and “internal drive S’s” which are met by the external stimulus excitation. But these treatments suffer from inability to supply anything but indirect (overt response) measures of the altered internal condition. By attacking behavior at the deeper level of total energy transformation, it is possible to apply more direct measures to the problem and thus improve understanding by improving methodology.

Strictly speaking, the first works on background energy condition are not energy studies at all. Response to a constant external stimulus is observed while the internal condition is altered by use of drugs, incentives, and other unmeasured excitants or depressants.¹ Some such construct as basic energy level, however, was early recognized as essential to the proper design of any experiments in this field. One pioneer study pointed the necessity of considering all stimulus-induced effects as change from a level (35). In other studies (46, 47) a regimen of eating, sleep, and exercise was set to provide a standard take-off point for

¹ It was the tendency of much of the early work on drug effects, etc., to consider the influence as acting directly on the stimulus-induced response. Thus alcohol, morphine, and nicotine were said to depress reflex reaction. Later, there was realization that such effects are indirect, i.e., produced by an alteration of the background energy condition of the organisms. Cf. R. Dodge and F. G. Benedict, *Psychological Effects of Alcohol*, Carnegie, 1915.

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experimental dosages of alcohol, benzedrine, and caffeine. Still other researchers (49, 66) ran basal metabolism checks to determine whether or not the subjects were in essentially the same starting condition at different periods of stimulation. Diurnal variations both in work output and the metabolic input level at first suggested some mystical inner clock in control of the background energy condition met by incoming stimulation. It took a long and arduous series of experiments (70) to show that such variations in energy level depend upon the timing of the heavy meal, the amount of exercise taken, and the length of sleep; changing the habitual organization of such factors also changes habitual levels of basic energy mobilization as well as the output of all overt response sequences built thereon.

Normally the waking energy background condition is considerably higher than that required to maintain essential life processes; but this also tends to be fairly constant for the individual, because of the habitual organization of the factors used to produce the general condition of readiness. Temporary jack-ups of the habitual readiness level occur under special incentive factors or when the total organismic system is alerted by drugs such as benzedrine or by hormones such as the adrenalin released in emotional response. Failure to discover and rid the subject of such transient excitants (or depressants) to his basic energy level vitiates many an otherwise well-designed experiment. Contradictions appear in the direction of observed response to a series of equivalent stimuli. If the experiment is concerned with the effect of some drug or other factor that itself acts upon the background energy condition, confusion is twice compounded.

By dint of trial and error procedure, most experimenters have now reached the point where they give considerable

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attention to the prestimulus condition of the subject. Metabolic studies have brought a gradual realization that the habitual readiness (basic energy) level of an individual is (a) the best starting point for experimental variations and (b) usually attained for all practical purposes by allowing from 15 to 30 minutes of quiet rest. Regardless of whether or not a metabolic check is run on the general background condition, anything introduced into the experimental situation must be regarded as a potential disturber of the energy level attained by quiet rest. Experimental alterations of this attained general condition have predictable effects on the quantity and quality of superposed specific S-R sequences. This is full justification for exercising every possible precaution when the object of research is to hold the energy background of response as constant as possible. The experimentally induced shifts in general energy level also constitute the first significant contribution to behavior study from the homeostatic point of view.

Effects of Experimentally Induced Muscular Tension. Backlash excitation from the muscles provides one of the chief means of altering the basic energy level. This is readily shown by differences between the sitting and standing pulse and by comparison of oxygen consumption records taken when the subject is relaxed and when he has tensed all his muscles. The fact that muscular tension can be systematically varied by instruction and instrumental devices has made this a very popular vehicle for research. The induced effects are also sufficiently strong to override effects on response by uncontrolled stimulants or depressants to the habitual energy level.

One of the earliest studies showed an augmentation of the knee jerk produced by tensing muscles in other parts of the body (103). The learning of nonsense syllables was

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found to be speeded up when the subjects grasp a dynamometer (3). Contrawise, muscular tension was reduced by progressive relaxation (94); reflex and sensory reactions to painful electric shocks was greatly reduced, and in some cases entirely disappeared (93).

Now the lowering of thresholds of specific part-reactions under tension increase and their raising under tension decrease may seem axiomatic. But there were many apparent inconsistencies. Data obtained in a wide variety of situations (5, 6, 16, 89, 96, 122) indicated that *increments* in experimentally induced muscular tension may increase the effectiveness of specific S-R activities, have no effect on them, or actually inhibit their operation. The first experimental attempt to relate these apparent contradictions formulated the problem as follows: "When may variation in the general energy background of specific adjustive response facilitate performance and when is it likely to inhibit?" Varying degrees of tension were induced at different times by having the subjects press on levers or sustain weights. Records of reaction time taken under conditions of "general relaxed state," "normal readiness tensions," and "hypertense state" showed definitely that a decline in the effectiveness of specific S-R sequences can be produced by both a lack and an excess of supporting tension processes in the general energy background (48).

This suggestion of optimal supporting levels for various types of adjustive response was amply confirmed in later experiments. It was found that the way the organism reacts to a displacing stimulus is as much a function of previously mobilized energies as of those directly aroused; in other words, overt reaction will attempt to homeostate the general energy level existing at the moment of stimulation. Up to a point, the higher this level, the more energy will the

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focal part-reaction discharge and expel. Beyond this point, the mobilized energies are likely to flow over into antagonistic response channels, with the result that the effectiveness of the focal reaction is decreased (46, 54).

More precise demonstrations of induced tension effects followed the pioneer exploratory studies. In one experiment scaled increments in (45) muscular tension, produced by pushing on levers, were found perfectly reflected in the palmar measure of general energy level. The effect of varying amounts of dynamometric pressure on nonsense syllable learning (45) and reflex reactions is generally facilitative to specifically adaptive response. The exact range of facilitating effect depends upon individual differences in habitual energy level, character of task, or complexity to response required for specific equilibrium of a displacing stimulus, and amount, locus, and timing of the induced tension process.

The problem of individual differences has been reported in several studies. Two found evidence that poor learners profit most from induced tension effects (5, 136); another study (17) reported a statistically insignificant difference in the benefits derived by good and poor performers. It is suggested that the alleged benefits to poor learners are a single energizing one; for in one study (19) individuals whose basic energy level was low tended to get the maximum benefits from induced tension. It has also been shown that the same degree of induced tension is not equally effective in all subjects (8).

The effect of similar amounts of induced tension on reactions of varied complexity has been studied in some detail. Work output in a simple task of finer oscillation was found to be increased in proportion to the amount of experimentally induced tension, while the accuracy of complex

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eye-hand co-ordination task was decreased under the same degree of tension increment (48). Another study of reflex reaction and learning scores also suggests that the more complex specific adjustments are best made with relatively little induced tension or other artificial jack-up to the habitual alertness level of energy mobilization. As learning of a specific adaptive response progresses, the optimal level of induced tension becomes lowered and above-optimal effects become more severe. Furthermore, excessive muscular tension induced during the interval following adjustive learning even interferes with the fixation of specific "traces" (19).

The amount of induced tension has been systematically varied, using reflexes, tapping, and mirror drawing as test performances (52). The last complicated and specifically adaptive task showed inflection to inhibitory effects earlier in the scale of progressively increasing tension than did the examples of low-order specific adjustive response. On the other hand, in so far as the overt manifestations of emotional response could be measured, this generalized motor reaction continued to discharge experimentally induced energies long after specific discharge outlets had become inhibited.

Studies of locus in induced tension effects show that under certain conditions a prestimulus increase in background energy condition can be preparatory for a particular part-response. One investigation (117), for example, indicated that the "voluntary" set for motor reaction has influence on the speed and amplitude of reflex response according as the associated tension is localized in muscles near to or remote from the reacting member. In another study (45) finger oscillation was found to be more rapid when the ipsilateral rather than the contralateral arm muscles sus-

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tained a weight. The definitive study (50) was made with supporting tension induced through weights and with the test response activated by faradic stimulation of the motor points of the forearm; here the facilitating effect was greatest when the weight-induced antecedent tension was localized in the faradically operated parts rather than in more anatomically remote muscle groups. Novocain nerve block abolished these facilitating effects, indicating the importance of backlash excitation. Timing of induced tension effect was also found to be an important factor; reaction time experiments (74) indicate that it takes a little while for voluntarily induced tension to raise the general energy level to such a point that overt discharge is affected. The optimal warning interval in reaction time experiments tends to correspond with the optimal timing of induced tension (33).

Timing, locus, and amount of induced tension are probably interdependent in influencing the activity of specific S-R sequences. It would appear from the reports already covered that a minimal amount of tension, localized in parts most utilized in a given response, will support performance more effectively than a maximum of tension, remotely developed. Time factors tend to become amount factors, and in maintained tension patterns there is reason to believe that the speedily reinforcing effects fall off as the reaction arcs become refractory. Any failure of experimentally induced tension (6) to influence records of specific overt response may be due to use of tension beyond optimal amounts, to improper timing of tension induction relative to activation of the test reaction, or to lack of consideration for the degree of practice represented by the work sample (19).

Gross Features of Energy Mobilization, Discharge, and

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Recovery. Having shown that experimental alterations of background energy condition affect the character of focal overt response, we may next study these gross energy transformations which support the specific equilibratory event. A stimulus is presented upon a known energy background and some covert measure of metabolic turnover is recorded. There is first an increment in metabolic activity, but as the stimulus effect ceases and the focal response becomes overt, the covert record begins to return toward the level from which the original change occurred. We can regard this general metabolic cycle as the best single index of total homeostatic behavior—a base of reference for understanding the energetics of those specifically adaptive part-reactions whose overt manifestations are the chief concern of the usual psychological investigation. The rising phase of this total curve is considered an index of organismic arousal or *energy mobilization*, its declining phase an index of organismic response or *energy discharge*, and the relation of the two an index of *recovery*.

We have already mentioned that palmar skin conductance changes provide a quick-acting indicator of minute energy turnovers in the intact organism. This covert response has been used extensively to study the gross aspects of *homeostatic response to external stimulation*. It has been found that for unexpected startle stimuli of equivalent intensity the skin conductance index is fairly constant for the individual, and that (other things equal) the metabolic effect is dissipated at a rate proportional to its arousal. Exceptions to this rhythmic course of events occur when the subject develops a learned set-expectancy or is otherwise affected by uncontrolled stimulation.

The best way to rid the system of intercurrent conditions, and thereby to study a typical equilibratory cycle,

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is to rest the subject prior to and between the test stimulations until the conductance index of basic energy level shows no major fluctuation for five minutes. From such an operationally defined basis, the per cent conductance increment becomes a reliable index of the degree of total organismic arousal induced by the stimulus. The part-reaction (such as a reflex) which is specifically adaptive to the stimulus usually reaches the stage of overt response as peak total energy mobilization develops. Following such expression or discharge, total energy expenditure declines, the per cent conductance decrement becoming a reliable index of the degree of total organismic discharge of stimulus-induced effects. The degree of total organismic recovery is reliably indicated by the ratio of the measure of energy discharge to the measure of energy mobilization (55). Problems that are pertinent to each of the three measures of total homeostatic responses will be discussed in turn.

Stimulus Intensity and Organismic Arousal. Systematic studies of the skin conductance measures have shown that as stimulus intensity is arithmetically increased this index of energy mobilization varies as the logarithm of its base (24, 73). This fundamental law holds not only for the general energizing responses of the organism, but also for activities of more limited part-reaction systems—such as the reflexes and the sensory pathways (see Figure 3). The earliest expression of law was made, of course, by Weber and Fechner in terms of so-called “sensation units.” Later it was found applicable to quantitative changes in reflex and learned reaction (118, 150). Its extension to basic metabolic process provides a deeper level of analysis for what has already been an important principle in psychology. For example, direct comparisons of the index of general

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organismic arousal can be made from different basic energy levels in terms of the per cent change in the record (73, 102).

One of the most significant aspects of the logarithmic relation of stimulus-induced energy change to its base is the fact that this index of organismic arousal will be greatest when a standard stimulus is imposed on the middle range of basic energy levels, and least at the extreme of the range. Just as weak and strong stimuli imposed on a median

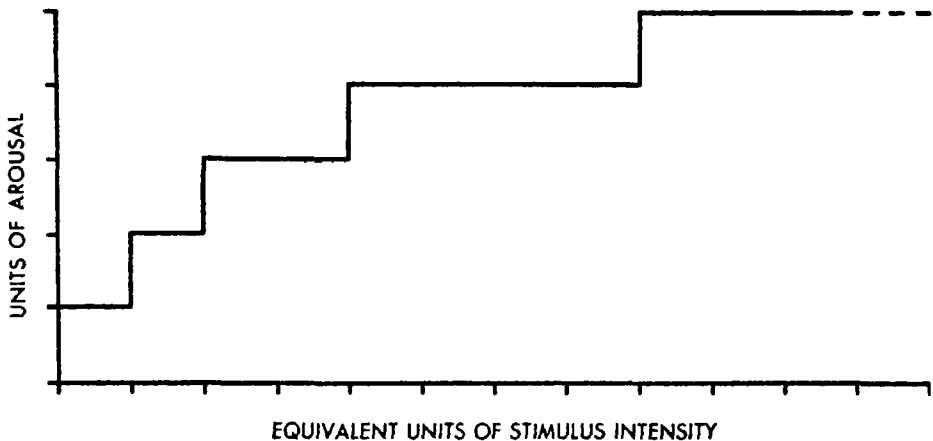


Figure 3. Degree of organismic arousal is relative to the energy level from which the stimulus-induced change occurs.

background energy level will cause relatively less mobilization than a stimulus of median value, so a median stimulus imposed on low and high basic energy levels will have similar limited effects. This means that an individual who is relaxed to the point of drowsiness or excited to a point bordering on emotional collapse will not react as effectively to specific stimulus displacement as he would from a normal alertness level. The basic energy level or background condition upon which stimuli are experimentally imposed usually varies from the lower end to the middle of the range. More work will have to be done at higher levels of

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mobilization before the energetics of homeostatic behavior will be fully understood.

Overt Reaction and Total Energy Discharge. We have already spoken of the declining phase of the total homeostatic response curve as indicating that energy discharge has occurred. While this statement is easy enough to advance on theoretical grounds, its experimental verification presents one of the thorniest problems in the entire field of behavior energetics.

Theoretically at least, both anabolic and catabolic processes are at work in every reaction to stimulation. At first the anabolic processes predominate, with the result that a measure of general energy expenditure shows increment. Later the anabolic processes begin to subside, catabolic processes begin to catch up, and the measure of energy expenditure shows decrement.

Now unless the excitation (anabolic process) aroused by stimulus is taken out of the system by expressed overt reaction, it continues to rearouse—and hence to maintain—the total disequilibrium. The proof of this statement is well understood by psychoanalysts; their patients provide ample evidence of long-continued intraorganic arousal because of the inhibition of overt reactions that would have discharged the energies originally aroused by stimulation. Among experimental psychologists, Lewin's ² students have shown that preventing the completion of a task makes for continued internal arousal; this is indicated by active memory traces of incomplete tasks, tendencies to resume interrupted tasks, etc. The definitive studies from the standpoint of behavior energetics involve a metabolic check on the effects of preventing adequate overt discharge of stimulus-aroused energies. With the interruption and in-

² Cf. B. Zeigarnik, *Psychol. Forsch.*, 9, 1-85, 1927.

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hibition of such stimulus-excited response as the knee jerk (10), micturition (53), or arithmetical computation (44), the general homeostatic response curve fails to show its usual decrement. Sometimes the inhibition of an about-to-be overt reaction is accompanied by a further increment in energy mobilization. In one experiment, such compensatory energy mobilization appeared to override inhibitory effects and force an equilibratory discharge (51).

If more adequate methods were available for quantifying the total amount of overt reaction in experimental settings, its relationship with rate of internal energy discharge would undoubtedly be more pronounced. An experiment (77) in which gross muscular movements of wiggling were recorded during displacing situations showed that this activity was accompanied by a rapid decrease in skin conductance measures of energy mobilization, but this was not the only overt behavior that discharged excitement. Casual observation showed that some subjects who wiggled very little during and after the displacing stimulation gained equilibrium by use of verbomotor mechanisms of discharge. This behavior included giggling, laughing, talking, and swearing at the experimenter. A measure of activity was attempted in terms of voice level or intensity, but interpretation of the records proved difficult. It is also presumed that the ideomotor discharge of "phantasy" is very pronounced in some subjects; the only indication of its importance as a discharge outlet comes indirectly through a study of the inhibited startle reaction (79). When subjects were restrained from writhing out of the way of a falling ball, not only was homeostatic recovery delayed, but also more reversals of a fixated "stair-case" figure were reported, indicating overactive preceptive activity in the situation.

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The next stage in the experimental investigation of the declining phase of energy turnover was the determination of the type of overt response that best produces this effect. Organismic reaction to even the simplest external stimulus is a very complicated affair. Many part-reaction systems are simultaneously or successively activated, and all to some degree express aroused energies. But some part-reactions (such as tics and motor automatisms) do not change the organism's relation to the stimulus field. We say these are not "specifically adaptive" because general arousal continues.

Failure to utilize measures of total energy turnover in defining specifically adaptive response has distinct limitations. It is common practice in reflexes, for example, to regard the most obvious overt part-reactions as being specifically adaptive, ignoring all the rest. But when we consider the jerk of the quadriceps muscle as the sole adaptive response to the patellar tendon stimulus and fail to study its relation to total energy turnover (along with less conspicuous circulatory, sympathetic, and associated spinal reflexes), we have lost the chance of defining the major expressive reaction in anything but superficial terms. Instead of having a formula for determining which of several contiguous part-reactions (overt or covert) is best suited to equilibrate a given stimulus displacement, we have only rough time-and-place-criteria for associating specific stimuli with their adequate responses and vice versa. Contrawise, in studies where the activities of a number of involved part-reaction systems are recorded simultaneously with a measure of total energy exchange (7, 34, 66, 101), close correspondence between the response curve of one of them and the decrement phase of total homeostatic adjustment will be noted. Such correspondence offers convincing proof

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that the reaction in question is, indeed, the one most specifically adaptive to stimulus displacement. If that reaction is prevented from reaching the overt stage of expression, other associated reflexes may be augmented; but the amount of decrement in general energy turnover will be much less for such relatively nonspecific modes of energy discharge. Finally, if the most specifically adaptive part-reaction—such as the ipsilateral knee jerk—is reinforced by excitation from higher neural levels, there is greater amplitude of overt response and more rapid decrement in energy turnover than in cases where the reaction is voluntarily inhibited.

The implications of these findings, done at the simplest level of neural integration, are very far reaching. We may infer that the continuation of varied response, as in trial and error learning, indicates some blocking in the appropriate channel of energy discharge; conversely, any decrement in general energy mobilization following stimulus-induced increment could be taken as evidence that some kind of overtly expressive discharge has occurred. The per cent energy decrement change could be used as an index of discharge, even when the involved part-reaction system is neither known nor recorded. Furthermore the more rapid the per cent decrement from the peak energy level (within the middle range at least) the greater would be the presumed intensity of the specifically adaptive discharge.

We shall have occasion to return again to the relationship between overt part-reaction and total energy discharge. Here we need only to sketch a gap-bridging hypothesis covering the general equilibrating effect of the specifically adaptive response. All behavioral discharge appears to excite the organism in some degree, because

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of chemical effects and backlash excitation from the muscles involved. It is presumed that every homeostatic behavior episode normally shows some specific part-mechanism, through the overt action of which the total organism becomes more equilibrated than displaced. The stimulus arouses a number of interacting part-systems to increased activity, and all follow a course from arousal to discharge. But when a discharge is specifically appropriate in relieving the stimulus-induced excitement, i.e., in changing the organism's relation to the original irritant, it appears not to re-excite the whole system but to backlash upon its own central connection (in line with Bok's principle of the reflex circle page 24), and in limited degree. Conversely, those part-reactions that do not specifically alleviate the irritating condition would backlash more diffusely and so help maintain the total system in a state of mobilization until a more equilibratory part-reaction was made.³

The Measure of Recovery. At first glance, it might seem that homeostatic recovery from stimulation effects was sufficiently indicated by a decrease in skin conductance or some other measure of energy turnover; but such measures do not take into account the relation of energy discharge to amount of original increment. Just as energy mobilization

³ This is not to be interpreted to mean that nonspecifically adaptive motor response hinders adequate equilibration. Elsewhere (page 16) we have pointed out that wiggling, nervous movements, and the like frequently take out more excitation than they put back into the system. These tend to be homeostatic-regulatory in situations where the organism is faced with mutually antagonistic behaviors (fight and flight), where goal reaction develops too suddenly to discharge all aroused excitation (premature ejaculation in the male), or where an external response-link is missing (courtship without copulation): cf. O. M. Tinbergen, "Die Übersprungbewegung," *Zsch. Tierpsychol.*, 4, 1-40, 1940.

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is related to stimulus intensity and energy discharge to intensity of specifically adaptive response, so recovery is related to quantitative interaction of these two phases of the total homeostatic sequence. A high degree of energy mobilization with a low degree of energy discharge indicates low recovery; an equivalent degree of each indicates perfect 100 per cent recovery; and on occasions when the intensity of discharge exceeds the intensity of stimulus-induced change there is supernormal recovery—reaction

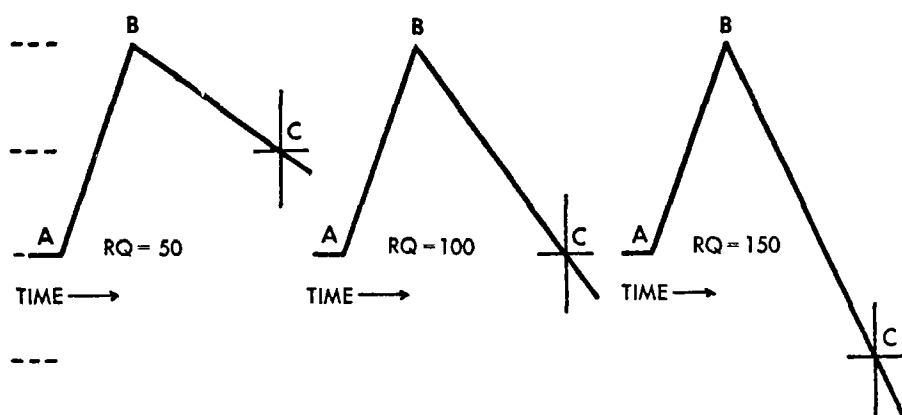


Figure 4. The homeostatic response curve. Recovery in neuromuscular homeostasis may be greater or less than 100 per cent.

having discharged prestimulus excitation and lowered the basic energy level. Such possibilities are diagrammatically represented in Figure 4.

It took a great deal of exploratory work to develop a workable estimate of total homeostatic recovery. Since it must, of necessity, be a ratio of discharge to arousal, the first job was to stabilize the measurement of these factors. Stimulus-induced changes in an index of total metabolic change (such as palmar skin conductance) were plotted on a time continuum. As indicated in the figure above from a point A representing a reasonably stable basic

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energy level for the subject concerned, stimulus displacement produced reactions by part-systems which at first mobilized more energy than they discharged. At the peak level B, the reverse over-all relation occurred, with overt discharge releasing more bodily energies than it re-excited. As anabolic processes began to catch up, general energy turnover fell toward the original level, at a variable point (C) on the time continuum. If one were to ignore time differences in reaching point C and were to divide the measure of energy discharge or response decrement ($\frac{B - C}{A}$) by the measure of energy mobilization or arousal

increment ($\frac{B - A}{A}$), the result would be 1.00, or perfect recovery. Such a measure, however, would be absolutely valueless in estimating different degrees in homeostatic recovery. What was needed instead was some method for combining both the time and amount differences represented in the plotted curves. Graphical and mathematical analysis finally showed the feasibility of taking *fixed points* on the time continuum as the place to measure A, B, and C values. We have already mentioned the operational definition of basic level A in terms of a point where the stimulus is imposed after the metabolic record has shown no major fluctuation for several minutes. From this point, the major increment in energy mobilization occurs within the first half minute after stimulation—regardless of whether the stimulus is sensory or ideational. Therefore point B can be arbitrarily defined as the level reached one-half minute after stimulation, even though this is frequently not exactly the “peak” condition. Furthermore, since the major decrease in energy turnover usually occurs within five minutes after stimulation, point C can be arbitrarily defined as the

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level reached five minutes after peak mobilization (B) or 5½ minutes after the momentary stimulation is given (A). With time relations of A, B, and C in this constant ratio,⁴ the degree of homeostatic recovery is reliably indicated by dividing the per cent discharge decrement by the per cent mobilization increment that occurred in the standardized periods of measurement. This fundamental integrative measure of neuromuscular homeostasis was given the name *physiological recovery quotient*. The formula $R.Q. = \frac{B - C}{B - A}$ gives a value of 1.00 for perfect recovery, the base (A) having canceled out in the computation. Usually, under these conditions of measurement, total recovery is not complete at five minutes after response to stimulation and R.Q. is less than one. Occasionally the subject continues to re-excite himself after withdrawal of the stimulus object, in which case R.Q. is reported as a negative value. On the other hand if energy discharge exceeds stimulus-induced mobilization R.Q. is reported as greater than one.

In order that experimental series need not be cumbered

⁴ This treatment of response energetics was made possible by the discovery that "recovery" in skin conductance and metabolic measures of reactivity is a regular function. A high correlation was obtained in rats between the per cent drop in rate of breathing five minutes after a stimulus-induced startle reaction had occurred and the length of time taken for complete recovery (101). In reactions of both human and animal subjects it was found that individuals reach peak reaction within a minute after cessation of stimulus and also tend to maintain the same rank in recovery regardless of whether the scores are based upon readings taken five minutes or ten minutes after this "peak." As might be expected, the readings taken five minutes after peak arousal were considerably more stable than were those obtained after the ten-minute period (58). For the application of the principle of "recovery from tension" (D.R.Q.) to the long-term adjustment sequences represented in a social case history—cf. O. H. Mowrer and J. Dollard, *Amer. Psychol.*, 1, 240, 1946.

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with R.Q.'s greater than one or less than zero, special studies were made of the conditions producing these anomalies. The negative R.Q. was found to be produced in two ways: (1) by the re-excitatory effects of attempted overt reaction not specifically adaptive to the displacing stimulus and (2) by new and uncontrolled stimulus displacement effects introduced during the discharge phase of the experimental sequence. Taking the C level of post-peak energy turnover very shortly after experimental stimulation tends to eliminate the occurrence of secondary stimulation; most of the negative R.Q.'s that show up in experimental series tend to indicate re-excitatory, non-adaptive overt reaction. R.Q.'s greater than one are a fairly common occurrence if the stimulus is imposed on an abnormally high basic energy level. When the normal alertness level has been artificially jacked up by drugs, undischarged energies from previous displacements, etc., reaction to the experimental stimulus often discharges some of this excitation of unrelated origin and the postresponse level falls below the apparent base. The best way to eliminate such records from an experimental series is to stabilize the basic energy level by having the subject maintain regular psychophysiological habits of work, feeding, and rest, and by "relaxing away" the effects of prior excitement. Proper control of both subject and experimental condition will go a long way to keeping obtained R.Q. measures within the wanted range from zero to 1.00.⁵

⁵ If physiological recovery quotients are derived from skin conductance measures of arousal ($\frac{B-A}{A}$) and recovery ($\frac{B-C}{A}$), the Weber-Fechner function is still included, even though the base A cancels out in the R.Q. formula; a full discussion of this problem appears in a study of the dynamics of the galvanic response curve (73). Some workers (99) have expressed the "galvanic equation" or R Q. in terms of resistance change.

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While it has sometimes been maintained that a stimulus brings about relaxation rather than excitation or displacement, there is rarely found an instance in which some mobilization does not occur. Even when the subject is so set on reacting to an awaited stimulus as to be actually rehearsing the overt response, the stimulus "trigger" raises excitation somewhere in the system before the equilibratory discharge is affected. Proper attention to subjective state and experimental situation will go a long way toward improving measurement of R.Q. changes to controlled stimulation.

The most significant systematic finding on recovery (R.Q.) is the fact that this integrative measure of total homeostatic behavior is independent of the basic energy level. Although it was by way of mathematical operations that the first hint of this independence appeared, it was not long before experimental evidence added weight to the argument. Everyone can see that in computing the R.Q. the base value (A) cancels out. Empirical proof of R.Q. independence was shown in an examination of skin conductance changes induced from different basic energy levels by a standard shock stimulus (73). Computed R.Q.'s did not differ significantly for the same subject even though the stimulus was sometimes imposed before and sometimes after the release of micturitional tension. The reason this correspondence held despite the fact that basic energy level was significantly higher before micturition than after is indicated in Figure 5.

This diagram shows the relationship of total homeostatic

Unlike conductance, these measures of physiological activity are not based upon a resting level and so do not take into account the level from which such changes occurred. Such formulation is in error, because of failure to express the Weber-Fechner function.

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response curves made to equivalent stimuli at different basic energy levels. The straight line from X to Y represents possible variations in basic energy level, while the exponential curve from X to Y represents the peak level of

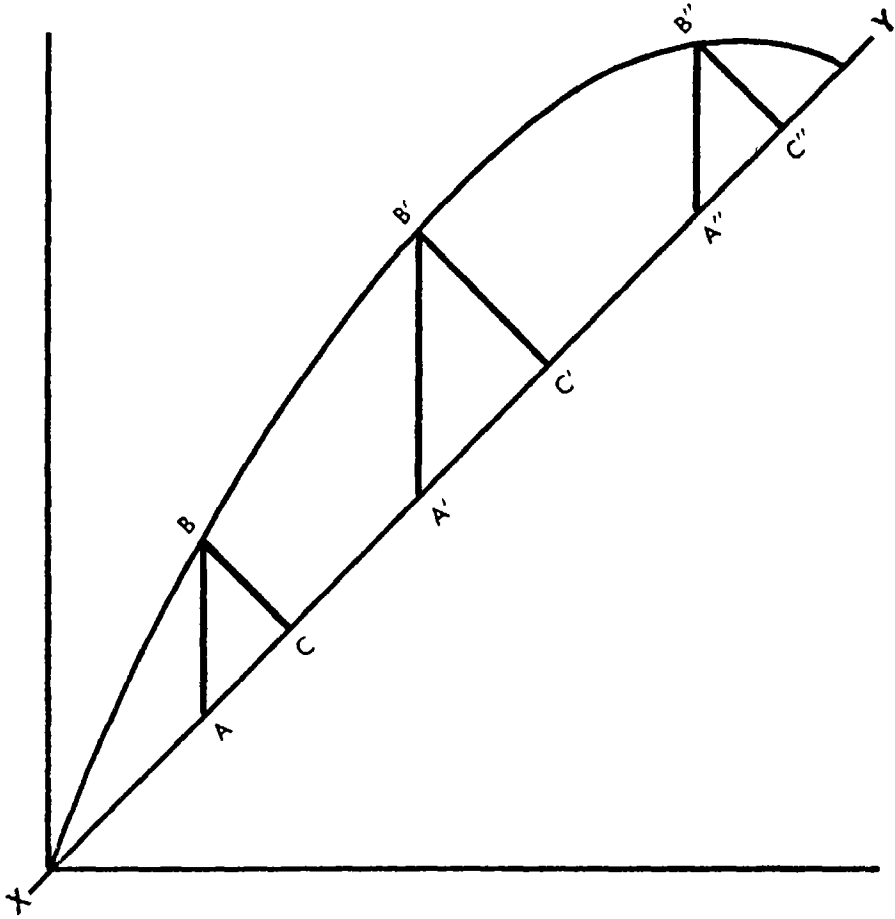


Figure 5 Homeostatic response curves (ABC) at different energy levels. The diagram shows that physiology recovery quotients (RQ) are independent of their base.

energy mobilization that will be elicited by a given stimulus intensity imposed at the various basic energy levels. The dotted triangles (ABC), which are representations of response curves from different basic levels, are seen as simi-

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lar; the ratio of ascending to descending aspects to the total curve is shown to be constant throughout, and the R.Q.'s, therefore, equivalent. This ability to compare computed R.Q.'s directly without reference to basic level differences between subjects or the individual's condition on different days is a matter of prime importance in later studies.

Total Energy Change and the Reaction of Part-Systems.

The psychologist will want to know the precise relation of overt stimulus-response sequences to the covert measures of general energy turnover previously discussed. This is a fair enough question, but one that has no simple answer. We have already mentioned that many part-reaction systems are simultaneously activated by a given stimulus and that the best assurance we have of identifying the specifically adaptive focal part-reaction is the correspondence between its response curve and that of general metabolic change. Such correspondence was readily shown for reflex integrations. But when the specifically adaptive discharge is a verbal response integrated cerebrally it is difficult to show correspondence between focal part-reaction and total energy change. Investigation, therefore, takes the form of relating the quantity of overt response in focal and non-focal part-reaction systems to the quantitative measures of energy mobilization, discharge, and recovery.

The effect of all part-systems concurrently aroused by stimulation appears to be summated in the per cent increment measure of total energy mobilization. Even though some part-systems are represented by a decrease rather than an increase in activity, the total over-all effect is positive because of the fact that excitation always exceeds inhibition in the initial phase of homeostatic response. Empirical confirmation of the summation of part-response in the measure of total energy increment was provided

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when blood pressure, breathing, and electrical records of muscle and brain activity were obtained simultaneously with the general metabolic measure during conditions of startle stimulation and ergographic work (59). The relation between total and part energy mobilization appears to be covered by the formula Y (total displacement effect) equals K plus ZX (summation of all part-system displacement effects). Standard scores representing relative amount of Y change are algebraically summed before being set in relation to the standard score of X change. Solving the formula at different energy levels gives a constant (K) value, which is probably the differential of part-systems not included in the experimental recordings.

Apparently, as activation of a part-reaction passes from the sensory to the motor side of the arc, there is greater opportunity for inhibitory circuits to block the overt discharge of excitatory circuits. Everyone is familiar with the fact that voluntary inhibition of the knee jerk is most effective when imposed just prior to the motor activation of the reflex circuit. Likewise, the voluntary inhibition of micturition does not affect total energy increment to a pressure stimulus on the bladder as much as it affects the normal decrement phase of the total energizing response (53). This work showed that unless the focal part-reaction reaches complete overt expression, the decrement phase of the total homeostatic curve will be arrested. In case the inhibitory processes require additional reinforcement, in order to prevent motor expression in the specifically adaptive focal part-system, there will be a further increment rather than a decrement in the total curve of energy expenditure.

Inhibition of the specifically adaptive focal reaction by instruction or threat of punishment does not, of course, prevent some discharge of the stimulus-aroused energies

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through auxiliary or substitute part-reaction channels. The tendency for internally aroused excitation to seek some channel of overt behavioral discharge in spite of all blocking is amply documental by the clinical material supplied by Freud and his students. Nor is objective experimental verification lacking. The more that specific adaptive part-reactions are blocked in problem solving and emotional conflict situations, the more do supplementary nonspecific part-reactions, such as wiggling, tics, vocalization, and visceral activity appear (69). These often increase somewhat the discharge index of the total homeostatic curve without, of course, bringing complete recovery.

The definitive studies of the relation of focal and non-focal part-reaction to total energy change is accomplished by comparing the R.Q. measure of total homeostatic recovery under conditions of specific and nonspecific part-reaction. When a specific verbal or motor part-reaction is blocked from expression so-called nonadaptive part-reactions such as restless movements increase (79). That these actually serve a homeostatic function is indicated by the fact that the greater this type of expression, the greater is recovery (R.Q.). If the displacing situation is an emotional one (for which no specifically adaptive part-reaction is ready-made) the greater the degree of nonspecific wiggling, vocalizing (swearing), etc., the greater the total R.Q. Even in problem-solving situations, where the focal response is permitted overt expression, excessive energy mobilization is worked off by auxiliary nonfocal discharges, such as foot tapping (60) and gum chewing (91, 92). Further studies of energy patterning aid in showing the relative effectiveness of focal and nonfocal part-reactions in producing recovery in the total homeostatic response curve.

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Finer Aspects of Energy Patterning. We come finally to the last type of experimental methodology used to develop facts relevant to behavior energetics. The previous paragraphs have mentioned the concurrent recording of stimulus-induced activity in several part-reaction systems. But that work sought mainly to indentify the focal part-mechanism whose overt response specifically equilibrated the total homeostatic displacement. Here we consider the *patterning* of part-reaction, focal and nonfocal, overt and covert, in relation to energy change. This is accomplished by shifts in the *energy distribution* produced by external stimuli, drugs, habituation, fatigue, frustration, etc. We investigate under what conditions the energies involved in response discharge are highly focalized in a single part-reaction system and when they are spread over a number of part-reaction systems. All auxiliary modes of existent behavior, such as tics, motor automatisms, and restless movements, are studied concurrently with the focal type of response, and some indication of the specific-nonspecific energy expression differential is obtained.

Since it is next to impossible to obtain quantitative measures of all the part-reactions—overt and covert—involved in a total homeostatic adjustment, experimentation frequently takes the form of simultaneous electrophysiological recordings from four or more muscle groups, one of which is designed to provide the most equilibrating specific discharge of stimulus-aroused energy (55). Sometimes these records indicate that neuromuscular activity is highly concentrated in the focal response part; again the energy discharge is more widely distributed, records showing about the same degree of activity in all muscle groups. The factors behind these shifts or redistributions in energy patterning are beyond the scope of this preliminary discussion

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of methodology. Here it is sufficient to point out that only when this type of study is made do a number of apparent anomalies become meaningful. For example, a shift in the pattern of energy distribution from four muscle groups to one highly specifically adaptive group is accompanied by improvement in overt performance (signaling arithmetic solutions), and with no increases in the general level of energy mobilization (55). Contrawise, the overt performance may remain constant, but involve progressively less total energy mobilization because of a more focalized (efficient) distribution of the energies with practice.

The dependence of total recovery upon the patterning of motor reaction requires special comment. While confirmation is far from complete, it seems probable that the *ratio* of focal to nonfocal neuromuscular activity provides one of the essential differences between effective and ineffective homeostasis. As was shown long ago in a study of the tensions of the used and unused hand during conflicting stimulation (105), the more that mobilized energies are discharged through the nonspecifically adaptive response, the less effective is overt response and the less rapid is total homeostatic recovery. Frustration studies with children (69) and distraction studies with adults (55) have both shown that a high focal, low nonfocal muscular tension differential accompanies the most efficient homeostatic response, when efficiency is measured either in terms of work output, work input, or both. Highly effective work and disorganized emotional discharge would seem to occur, therefore, at opposite ends of a continuum of energy distribution. On this continuum, the optimum condition would be a low level of general tension extended to all the reactive muscles of the body and sustaining quick shifts of intensive tension increments to the muscles specifically involved in

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various task demands. No individual could give specific expression to all mobilized energies with equal ease, but, on the average, some would excel others in this regard. If, as we expect, such differences are due to acquired reactive postures, the possibilities of learning in homeostatic adjustment are enormously increased. Anyone can see that from this point of view the whole concept of work efficiency requires a drastic overhaul.

Work Efficiency and Homeostatic Resiliency. This introduction to the general characteristics of neuromuscular homeostasis ends by a consideration of methods for measuring the efficiency of adjustment. There was a time when work efficiency was measured entirely in terms of overt reaction, the quantity and quality of organic output. This made the high-rate piece worker the most "efficient" man. But an output measure failed to satisfy critical students on two counts: (1) It paid no attention to how much energy input is needed to produce the highest work output, and (2) it ignored long-term residual effects possibly resulting from work at high output levels.

It is now generally recognized that work efficiency must be measured in terms of the relationship of work output scores to work input scores. One of the first studies (64) dealt with the metabolic costs of work at different levels of neuromuscular homeostasis. It was shown conclusively that long-continued performance is impractical at high levels of input arousal or energy mobilization. The law of diminishing returns operates in the input-output relation. If it takes five units of energy input to produce the first five units of work output, the next five output units may be achieved only by expenditure of correspondingly greater energy input units.

Direct comparison of input and output units has, of

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course, always been easier in speculation than in practice. But some of the measures developed in previous sections of this chapter are directly applicable to the problem. It can be seen that the true measure of organismic input is the total area under the general homeostatic response curve. Likewise, the true output measure is a summation of all overtly expressed part-reactions. Such composites being difficult, if not impossible, to obtain, a characteristic index of each aspect has to be taken. After long trial and error, the best single solution appears to be the use of peak energy mobilization against peak overt discharge in the focal response. When such input and output measures are figured in terms of standard scores, it is possible to write a formula for work efficiency as follows:

$$\text{Organismic efficiency (under given experimental condition effects)} = \frac{\text{Per cent focal output increment}}{\text{Per cent total input increment}}$$

Of the two things wrong with this rewriting of the efficiency formula, the first is not as serious as it seems. It can be argued the per cent increment in *nonfocal* responses may be rightly ignored, because of the fact that the more a person expresses aroused energies through focal part-reaction, the less does he expend through nonfocal, non-adaptive reactions (69). In other words, an intense focal part-reaction causes the majority of energy discharge.

It is far more serious to let per cent total input increment stand for all the internal effects produced by stimulation. Clinical psychologists have long maintained that internal residuals from work at high energy levels carry over and affect organismic adjustment long after the "efficiency" of a limited work sequence has been studied. This seems to have objective verification in the amount of residual muscular

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tension recorded when work is done under supernormal conditions of effort, as with sleep loss (47). If the capacity to rid the system of stimulus-induced effects were a direct function of the degree of energy mobilization, the present efficiency formula might suffice. But it is by no means axiomatic that the person with the highest energy input will have the greatest difficulty in achieving complete homeostatic recovery or vice versa. Many individuals are found to turn out a maximum of work output with a minimum of energy mobilization who fail, none the less, to show rapid recovery and homeostatic resiliency. Such a person may attain a good efficiency score under experimental test conditions, but be so constituted he gets rid of the stimulus-induced effects very slowly thereafter. Either the so-called focal response is not taking the major portion of induced energies out of the system, or—what is more likely—some unnoted nonfocal response, fortuitously developed as an auxiliary discharge mechanism for peak energy input, continues to reactivate itself and so prevent the return of the total homeostatic response curve to the prework level. Tics or motor automatisms and vocal and ideomotor reactions might operate thus to maintain a residual tension load and prevent complete recovery between work periods.

It is proof of how far we have yet to go in the energetics of total behavior that only the barest suggestion of a reliable index of homeostatic resiliency can be made at this time. The ultimate criteria may lie in some record of the daily or monthly course in basic energy level. Such levels have been plotted for a small group of students from the beginning to the end of their school year (139). The impressive thing about the records is that some individuals show a progressive rise in the basic energy level as the

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work of the year makes increased demands and as unexpressed or self-maintained residual tensions mount. Other individuals may show a limited period of heightened basic energy level, as during examination week, but have an over-all constancy. This would seem to indicate a resiliency in dissipating stimulus-induced effects so that these are not carried over to influence bodily activity levels in the periods of sleep and rest imposed between tasks.

The basic difficulty with even the best of present efficiency formulae is that they are a product of cross-sectional analysis. There is a temporal factor that cannot be worked into the ratio of output to input, and the measure of recovery from a single behavior episode is not known to bear any predictable relation to long-term residual effects from work at high energy levels. When research in neuromuscular homeostasis has progressed further, we may hope for a valid temporal characteristic of response that will fit without distortion into the momentary input-output relation that presently dominates our concepts of efficiency.

Of the three methods used to study behavior energetics, only the last holds much hope for unraveling the complexities of efficiency measurement. We know that *experimental alteration of energy background condition* produces positive and negative effects upon the work output of the specific adaptive (focal) part-reaction. Studies of the gross or *total energy transformations that accompany a work output* series give us essential knowledge of input condition. But only studies of the *way aroused energy is distributed among the part-systems* involved in response discharge can really differentiate the efficient from the inefficient behavior episode. Too many people now being credited as efficient workers toss around at night with insomnia, have psychosomatic upsets and other indications of residual effects from their

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day's work. It is not enough to say that such conditions are bad. We must learn why they are bad and how the individual acquired these particular products of attempted homeostatic discharge. Perhaps some measure derived from the study of concurrent part-reactions will indicate the presence of habitual discharge patterns regardless of type of stimulus imposed. Perhaps we shall even come to refer to individuals whose energy discharges favor a particular part-reaction system—regardless of its appropriateness—as “discharge types.” Certainly the extension of the basic methodology developed in this chapter to complicated behavior problems will not be far advanced without some set of constructs to bridge the present gap between detailed experimental research and rough clinical evidence.

Principles of Homeostatic Behavior

Levels of Homeostatic Adjustment. Application of homeostatic doctrine to all varieties of total behavior requires a number of gap-bridging constructs. The first of these is *adjustment level*. In maintaining essential constant states and preserving its identity, the organismic energy system has several lines of defense, or levels of adjustive response. The organ or cell is the primary immunological level of defense. A higher and more complicated level is found in the generalized emergency reactions of the total organism, integrated via the autonomic nervous system. The highest level involves cerebrally controlled total behavior, including response that is specifically adaptive to external stimulation and the so-called “ego defenses” that guard the inviolacy of the personality from psychological insult.

If the organism were an entirely closed and self-perpetuating energy system, it is doubtful if anything more elaborate than the first level of homeostatic response would be needed to maintain the constancies of the fluid matrix. When calcium, sugar, and other essentials were needed by one part, these stores would be released by another part not needing them, and returned thereto as that part itself made special demands. But the materials and products of

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metabolism are not so conserved within the system; instead they are dissipated into and must be continually replenished from the outer world. Consequently some higher order adjustment levels are needed to relate the demands of the internal environment with the opportunities of the external environment, and vice versa. The neuromuscular system was developed for exactly this purpose. Its autonomic control centers are a more effective coordinator of internal constancies than are organs operating directly on the blood stream, and its cerebral control over skeletal muscle action puts the organism into active contact with the external environment. Neuromuscular homeostasis constitutes, therefore, an essential addition to limited organ homeostasis and an enormous reservoir of adjustive power.

Although it may sound farfetched at first, we should properly regard complicated total behavior and the maintenance operations of such organs as the liver as both directed to the same ultimate end—internal quiescence, relaxation, and the preservation of essential life constancies. In fact, the organismic energy system is organized so that homeostatic functions are taken over in a progressive fashion from lower to higher levels, as one after another fails to achieve adequate adjustment. A good illustration of this principle is found in calcium maintenance. This essential element in cell metabolism is stored or released by the bones, according as its relative presence or absence in the blood stream warrants. Abnormal demands are sometimes made upon these stores, as when the pregnant mother must supply extra calcium to the developing fetus. But if the calcium content of the blood stream is not adequately maintained at this primary level of adjustment, calcium-sensitive receptor tissue excites the autonomic division of the neuro-

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muscular system and this in turn activates the parathyroids to push other tissues into releasing calcium stores not readily attachable by direct humoral actions. Finally, if this autonomic regulation of the internal environment is inadequate, other sensitive receptor tissue is stimulated by the calcium lack and this leads, via central nervous control, to overt muscular action calculated to replenish calcium stores from foods found in the external environment.

All degrees of elaboration of externally oriented "adjustment" can be built through conditioning upon such basic demands as "calcium need." Such externally directed reactions are still connected with internal regulation processes, and follow an equilibratory course leading to internal quiescence and a general organic state favorable to the maintenance of essential constancies.

Neuromuscular Homeostasis: A.L., D.I., and R.Q. The previous chapter gave us means of investigating the equilibratory energy transformations induced by external stimulation. They also open the way to an operational definition of three important aspects of neuromuscular homeostasis, or total behavior.

If one examines the response curves of typical part reactions, such as reflexes, or the total energy changes that accompany and support such overt expressions of stimulus displacement, their form is generally found to be the same. The ascending portion of the curve may be described as S-shaped, while the descending phase appears as a mirrored S. While the rate of rise and fall are consistently related in a normal progression toward equilibrium, the possibility of inhibition and blocking render necessary a separate expression for each aspect of the response curve and for their obtained relation.

The Arousal Index (A.I.) is a term used to describe that

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feature of behavior (total or part) wherein bodily energies are mobilized to meet the threat of external (or internal) stimulation. It is a construct dealing with excitability, the sensory aspect of reaction arcs, a measure of the extent to which the organism (in whole or part) is aroused by stimulation. The arousal index of particular part-reactions can be estimated in terms of their thresholds of excitability, while that of the organism as a whole can be estimated either by the percentage increment in total energy mobilization to a typical startle stimulus or by some quantitatively graded test of general irritability (71). When we are dealing with excitability to specific types of stimulation, we use the term *specific arousal index*; when we are dealing with excitability to various types of stimulation, we use the term *general arousal index*. The A.I. obtained under actual test conditions is thought to have some predictive value. Nowhere, however, is there any implied relation between A.I. and other aspects of homeostatic response, beyond the fact that a high A.I. places great demands on the motor processes for adequate expression and release of stimulus-aroused energies.

The Discharge Index (D.I.) is a term used to describe that feature of behavior (total or part) wherein aroused bodily energies are expelled through action. It is a construct dealing with activity, the motor side of reaction arcs, a measure of the extent to which the organism expressed aroused excitation overtly.

No special proof is needed to show that activity tends to equilibrate stimulus-induced displacement and bring about relaxation through cessation of excitatory effects. The spinal frog reacts to the placing of an acid paper stimulus on its skin by brushing off the irritant. At the more complicated level of trial and error learning, the

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equilibratory action also "does something about" the stimulus effect. Though it may not remove an irritating condition directly, any form of overt activity—from solving crossword puzzles to hard muscular work, verbalization to wiggling—helps to reduce internal arousal. Not all activity is, of course, equally effective in discharging aroused excitation. Some actually rearouses, putting more excitation back into the system than it takes out. The check, therefore, of the discharge feature of activity is whether or not the rate of energy turnover is reduced thereby.

The discharge value of particular part-reactions can be measured in terms of the degree of correspondence between their cessation and the decline in associated excitatory energies. The discharge index of the organism as a whole can be estimated either in terms of per cent decrement in total energy turnover or by some quantitatively graded test of general expressibility.

As with the A.I., the D.I. is presumed to have predictive value. No direct relation, however, can be made between discharge and recovery, since a high D.I. could as easily evidence overreaction and re-excitatory effect as stand for the most complete expulsion of stimulus-aroused energies.

The Recovery Quotient (R.Q.) is the integrative measure of homeostatic response, a term used to describe the relationship between the arousal and discharge features of behavior (total or part). It is a construct dealing with the degree of balance or unbalance in neuromuscular homeostasis.

The R.Q. of particular part-reactions can be measured by the ratio of rise to fall in their response curves. That of the organism as a whole is estimated either by dividing the percentage decrement in total energy change by the

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percentage increment, or by the relation between quantitatively graded tests of general irritability and general expressibility. These values are used in reference to actual behavior outcomes and also for purposes of prediction. A high R.Q., for example, presumably indicates rapid equilibration of stimulus-induced displacements, a state of internal calm, and relaxation. A low R.Q. indicates slow equilibratory processes—a state of continued internal excitement, the presence of considerable self-maintaining tension.

Compensatory Energy Mobilization. The principle of compensatory effort is already so well recognized in experiments on fatigue, sleep loss, and distraction that we here need only place it in a homeostatic context. Whenever an act-in-progress meets with resistance (because of internal or external causes), there is a tendency for the organism to mobilize additional energies. Such reinforcement serves to carry the act-in-progress on to completion, thereby attaining the total equilibratory effect. Sometimes these increments of effort more than compensate for the resistance imposed. In such instances, the *overcompensation* is not wasted, but serves to drive the response discharge mechanism to a higher level of accomplishment. Heightened overt performance under so-called “*distraction*” is frequently taken as evidence of compensatory effort; however, the precise measure can only be supplied when concurrent records of energy mobilization are taken. With these measures, any increment over the stimulus-induced arousal (A.I.) connected with the total equilibratory sequence is evidence of compensatory mobilization.

Overt Response and the Principle of Backlash Action. There is no simple way for representing the fact that organismic equilibratory forces are overt reactions that

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bring about internal recovery indirectly by discharging and diffusing aroused excitation. Every stimulus (internal or external in origin) sets up a series of organic processes. Some of these are excitatory, catabolic, tearing down reserve energies. Others are relaxing, anabolic, rebuilding the prestimulus level of metabolic balance. In neuromuscular homeostasis, whether in specific part-reaction or the more widespread total changes in bodily activity, the rising phase of response is thought to indicate that the responsible energy transformations are more displacing than equilibrating. In other words, stimulus-aroused catabolic effects gain an early ascendancy over compensatory anabolic buildup processes. The aroused excitation effect must be expelled from the system; otherwise the slower acting restorative effect will never catch up on the rate of catabolic teardown and the total organismic system be maintained at a new high and metabolically costly energy level.

Now expulsion of catabolic effect is something more than the activation of a channel or motor discharge. Every overt response that is made has re-excitatory (neural and chemical) backlash effects. Hence the equilibratory discharge must rid the system of more excitation than it puts back in. Only when the catabolic energies expended through overt response exceed those aroused by new or continued excitation will the peak level of the homeostatic response curve have been reached. This peak level is thought, therefore, to indicate the transformation point where overt expenditure of aroused energy begins to overcome the displacing effect of stimulus excitation and when anabolic restorative processes begin to catch up and exceed catabolic processes.

The consistent relation of rise to fall in the majority of simple response curves suggests the use of a physical anal-

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ogy—the trajectory of projectiles—to help visualize the interaction of opposed organic forces, catabolism and anabolism. When the height of a projectile is plotted on a time continuum from the moment it leaves the earth until it again hits the ground, the shape of the curve is roughly similar to that recorded for a homeostatic response sequence. Analysis of the forces responsible for the form of the trajectory also presents similarities. The projectile is ejected by a stimulus charge. As soon as it leaves the ground level, re-equilibratory gravitational force comes into play to counteract the stimulus displacement. At first the forces of stimulus displacement are greater than those of gravitation; but as the projectile mounts, the ratio between the two forces approaches zero. At the peak of the trajectory, the projectile stops dead for a split second, as a reversal in ratio takes place. The energies of the firing charge now having been dissipated and expelled, the restorative gravitational pull is unopposed and the projectile begins to return to its original position on the ground.

A more dynamic situation, and hence a closer analogy for organismic reaction, is to imagine the projectile as a rocket with its ascendant energies only partially aroused by a small external charge. As long as self-contained explosive charges produced displacement forces greater than the restorative forces of gravity, the projectile will rise; when they are equalized the peak of the trajectory is reached; as the balance of forces favors gravitation, the rocket drops to the ground.

The organismic response curve will, of course, be much more variable than the curve of rocket reaction, both with regard to temporal sequence and quantity of energy exchange. Also, in the rocket, the equilibratory forces of gravity are constant and external to it, whereas in the or-

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ganism these forces are internal in origin and variable in nature. The main use of the rocket analogy is its representation of organismic equilibration as the interaction of opposed forces. The change from predominance of teardown to predominance of buildup occurs, by analogy, when aroused reaction arcs discharge and diffuse more catabolic energies through overt response than their backlash effects remobilize, thereby enabling anabolic processes to catch up.

The hypothesis that every motor response reports centrally by backlash action has many important implications. First and foremost, it helps explain why some overt responses bring relaxation and quietude, whereas others only increase internal excitement and raise the general energy level. The most adaptive response is not necessarily the one which brings most rapid and complete recovery from stimulus-induced excitement. Such recovery is accomplished, by hypothesis, when the central backlash effects of the response in question are specific rather than generalized; that is, the motor processes report back neurochemically to the specific centers generating the action instead of diffusing the re-excitatory effect. The relation of such specific effects to "trace theories of fixation" is a matter of vital concern in the psychology of learning. Contrawise, nonspecific backlash effects may be invoked to explain why conflicting, blocked, and inappropriate reaction to frustration stimuli raise rather than lower the general level of internal excitement. It appears that (other things equal) the more the motor response to stimulation is specifically concentrated in a limited number of reaction arcs, the less is its over-all re-excitatory effect. Furthermore, the more specifically the major part response is connected with "doing something about" the stimulus the less the total backlash excitation. Presumptively, the ratio of

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specific to nonspecific backlash from overt response has even greater bearing on the subsequent pattern of energy distribution than it has on total quantitative changes in general energy level.

The Focal Background (F.B.) Response Ratio. Psychologists are so accustomed to concentrate on the focal part-reaction obviously connected with stimulation, they all but forget the nonspecific background responses that are concurrently expressed. Motor automatisms, tics, and nervous mannerisms or accessory reactions such as gum chewing, smoking, and pacing often play a vital role in helping expel stimulus-aroused energies. Under certain circumstances, as when the induced excitement is very high, they serve as safety valves, indirectly increasing the effectiveness of focal performance. Again, their facilitative effect may not be to expel an overplus of stimulus-aroused energies, but rather to discharge some long-continued and internally maintained excitatory effect, thereby lowering total energy mobilization to a level more conducive to effective discharge of stimulus-induced excitement.

Since the part-reactions involved in a total homeostatic response may vary all the way from one to uncounted numbers, some construct is needed to cover the "spread" of stimulus-induced effects. This construct is provided by the *focal-background (F.B.) response ratio*—an estimate of the distribution of the quanta of stimulus-aroused energy in the pattern of expressive action. Such an index of the relative intensity or concentration of expressive effects is obtained by comparing simultaneous records of the activities or tension level of two muscle groups, one set for focal part-reaction, the other relatively unrelated to the stimulus situation and, therefore, presumably symptomatic of background part-reactions. If the stimulus-induced change is

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greater in focal than in background muscle action the F.B. (or specific-general tension) ratio indicates concentrated channeling of overt discharge. If, on the other hand, stimulus-induced change is equal in both focal and background response, the F.B. ratio indicates a diffuse channeling of overt discharge.

Luria (105), whose pioneer study of tension in the used (signaling) and unused hand during conflict stimulation first showed the importance of the F.B. response ratio in reaction dynamics, has expressed the view that unless a specifically organized motor outlet is ready and available, stimulus-aroused excitement will spread diffusely to many organic parts. We would extend the hypothesis further: assuming a given quanta of energy mobilized by a given stimulus, the most homeostating effect will be produced when the patterning of the expulsive discharge favors a high degree of concentration in the specifically adaptive part-reaction and a low degree of activity in nonspecific muscle groups. Such an assumption says nothing of energy reserves and makes no predictions of the total amount of energy to be mobilized. It simply indicates that of the total energies mobilized by stimulus the amount spent in maintaining diffuse general tensions and background part-reactions is not available for driving the focal part-reaction to highest effectiveness.

A final caution is needed in applying the *F.B. response ratio* construct to all varieties of behavior. Sometimes the overt response considered "focal" in terms of inherent S-R connections may not be the one actually serving as the major outlet of aroused excitation. Psychiatrists have reported abundant clinical evidence of substitutes for blocked and inhibited natural response. The same thing was shown

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experimentally, when voluntary inhibition of the protective lid reflex (117) was accompanied by increased wiggling and finger drumming; these natural background reactions had actually become focal, expelling more aroused nervous energy than the winking response "most called for" by the stimulus. Such results suggest that the best and soundest test of the focus of response discharge is a correspondence of some part-reaction response curve with decrement in general energy level. Other things equal, there should be correspondence between a high F.B. ratio in the patterning of part-response discharges and a high R.Q.

Habitual vs. Available (Ceiling) Energy Level. All foregoing discussion has presupposed *reaction from a level*. Whether dealing with the arousal or discharge aspect of the homeostatic response curve, specific or general effects, focal or background behavior, we have consistently implied a prior organic condition that greatly influences the outcome of stimulus displacement. The construct of *basic energy level* is essential to either discussion or measurement of neuromuscular homeostasis. It is, by definition, the internal condition from which the organism is displaced and toward which the overt response discharge tends to produce a return. We have seen (page 85) that a fairly good estimate of this "take-off point" for action is obtained by relaxing the subject until some measure of total metabolic turnover stabilizes itself, showing no major variation for five minutes. Following temporary increments due to electric shock, brusque personal questions, and other stimulus displacements, experiments (72) have shown that metabolic activity tends to return to a fairly constant level. This does not mean, however, that basic energy level is inherently fixed. Though it is habitually stabilized around a certain

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rate of metabolic exchange, any drastic reorganization of the individual's regimen of sleep, eating, and work will produce a rise or fall (49).

*The basic energy level attained in experimental series is thought to represent the metabolic demands of the persistent internal conditions of alert rest.*¹ Normally this level is slightly in excess of the basal value needed to maintain life processes such as breathing, digesting, eliminating, and keeping the body cells in working order. Basic level can probably be set off from basal (BMR) values by some order. Such criteria as the reappearance of alpha waves in electroencephalograms is a characteristic of basic energy level. For while the basic alertness level is closer to the minimum energy essentials of life (as in deep sleep) than it is to the level attainable under the highest conditions of arousal (as in maniacal excitement), it is not a basal metabolic rate.

It is recognized that energy has a ceiling as well as a base and that there are wide individual differences in the range of available energy mobilization. This inevitably influences the pattern of response adjustment. A high-energy person will have, by definition, a great range between basic and ceiling levels and will require a great many activities in order to utilize his great store; conversely, a low-energy person will have to avoid overcrowding his pattern of living else the effort to act beyond physiological capacity will exhaust him.

While we like to think that a high basic energy level also indicates an extensive range of available energy mobilization, the obtained measure of habitual alertness does not necessarily predict a high ceiling. Sometimes a high basic

¹ H. Head (*Brit. J. Psychol., Gen. Sect.*, 14, 126-147, 1923) has discussed a similar problem under his concept of "vigilance." Ultimately we may approach its precise measurement.

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level simply indicates that the person is operating on an artificially jacked-up level, far nearer his ceiling value than its normal position—slightly above the basal metabolic rate of restful sleep. Prolonged work demands and raised standards of performance narrow the differential between actualized and ceiling values. A cumulative load of undischarged excitation, if it becomes self-perpetuating, also helps create an abnormally high rate of energy mobilization. People who habitually live on such a false basic level “live on nerves.” Reactions therefrom have but little reserve to draw on, overt response tends to become inept and ill-adaptive, and the individual approaches his breakdown point of total homeostatic adjustment.

The notion that the organism possesses a certain amount of “adaptation energy” is by no means new. Many writers have hypothesized that when such energy is being employed to combat one type of displacement, less is available for reacting to other stimulation. No one, however, has shown how this theory can be released from the bounds of vagary and subjected to experimental check. Study of the homeostatic sequence under varied conditions of work load is the only feasible approach to the problem.

It would be impractical to increase stimulus load until a human subject's ceiling level of energy mobilization was reached, for this would bring permanent injury. However, some estimate of relative differences in range of available energy mobilization is provided by comparing changes produced in homeostatic response curves under two conditions of stimulation. For this test a standard startle stimulus, such as a pistol shot, is imposed during the normal resting state and again when the subject is already displaced by a competitive work situation. Exploratory studies (62) have indicated that some individuals equilibrate the startle dis-

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placement as readily when it is superposed upon high-energy mobilization (competitive work) as when it is given on lowered conditions of effort (quiet rest). It is presumed that such individuals have a great deal of available energy, for even under load they meet the superposed demands of startle displacement with adequate energy mobilization. On the other hand, individuals who show disruption of work under superposed startle stimulation are presumed to have very limited energy reserves. It also appears that the less the superposed (startle) effect from resting to working conditions, the less the effectiveness of response. A low energy differential between the two conditions might well be regarded as indication that ceiling values are being approached; another possible indication would be a sluggish recovery from the effects of stimulation. Both the mobilization differential (from superposed quiet to superposed work stimulation) and the R.Q. might thus constitute indirect measures of the extent to which a person's habitual basic level of energy mobilization approaches his ceiling level.

Clearly the basic energy level—naturally high or artificially jacked up—will set the amount of energy which will be mobilized to a given stimulus displacement. We have already seen (page 87) that when basic energy level is low, arousal increment is also low, and that similar small increments occur at high energy levels. Only in the median range of basic energy levels do we get the greatest stimulus-induced increments (46, 73). If it also appears that quantity of discharge and quality of overt response are similarly effected at high and low energy levels, the way is open to another essential construct in neuromuscular homeostasis.

The Optimal Reaction Range. The homeostatic adjustments

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of organ part-systems, such as the liver, reveal many instances where elevating and depressing mechanisms function to maintain within narrow limits essential constant states such as the blood sugar level. It is presumed that the nervous centers controlling total behavior adjustment also function most effectively over a limited range of excitation. But externally directed neuromuscular homeostasis lacks the rigid checks of internally regulatory processes and so overt response is possible over a wide range of energy mobilization. Beginning with a condition akin to sleep and proceeding to the near ceiling level characteristic of intense emotional excitement, the A.I., D.I. and R.Q. of superposed homeostatic response curves, as well as the quantity and quality of specifically adaptive focal part-reactions, are similarly affected. At extremely low energy levels, arousal and discharge are low, performance sluggish, and recovery slow. In the median range, however, effects are optimal. Beyond this further energy increment gives gradually diminishing returns until a point is reached where specifically integrated total behavior breaks down, overt reactions are of the generalized emotional type, and recovery is low.

We refer to this condition of most effective energy level as the *optimal reaction range* and verify the necessity for the construct by showing experimentally that an individual's behavior is less effective when superposed on low and high energy levels than when superposed on a median level (51). The relations involved are shown diagrammatically by plotting a measure of the quality of overt response against a measure of the quantity of basic energy mobilization, with the optimal reaction range set off by shading.

Figure 6 is intended to provide a paradigm for all further discussions of the optimal range concept, including variations between individuals, with type of stimulus displace-

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ment, and with type of focal response discharge.² Numerous checks, such as relative fatigue, motor automatisms, and restorative sleep act to prevent the organismic energy system from working beyond its optimal range; but these safeguards may be systematically offset by prolonged abuse of the bodily economy. For example, because of individual

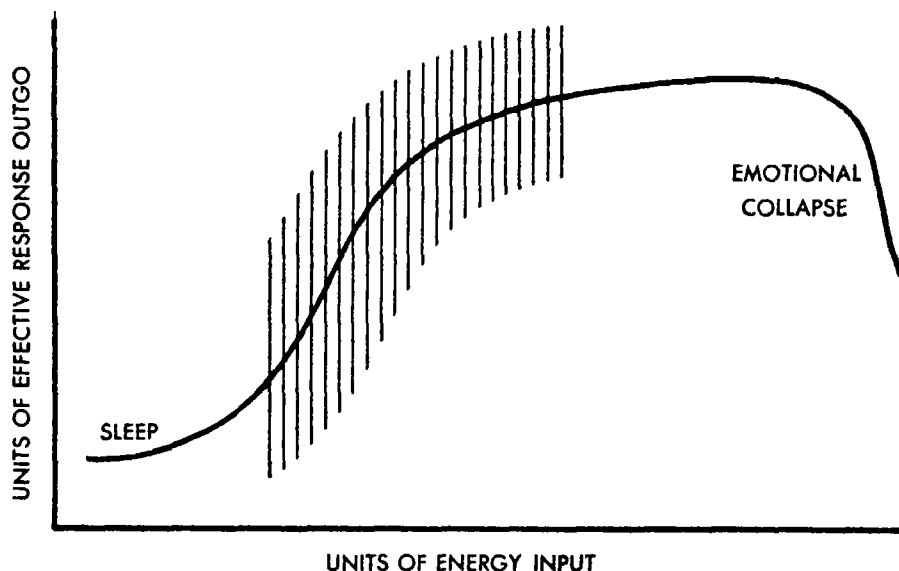


Figure 6. The optimal reaction range.

differences in discriminative capacity, it is possible that the standard of adequate performance is above that naturally attained by the person under examination. In attempting to maintain such a standard, this person tends to

² Not only is performance most effective in the median range of energy mobilization; it also operates most efficiently in the median range of other influencing conditions. If, instead of energy mobilization, the base line of Figure 6 were labeled *degree of similarity between performance and the previous task, amount of spacing between rest-pauses, etc.*, we should still have a curve of relationship in accord with the facts. It thus appears that the optimal range concept is basic to neuromuscular homeostasis and that many statements of the "best" conditions of performance could be rationalized by its use.

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work his system considerably above its optimal reaction range. Since recovery from stimulus-induced effects is sluggish at high levels, the system moves progressively nearer its potential ceiling, as undischarged excitation residuals do their daily bit toward raising the basic energy level. Regardless of whether the disequilibrium behind such excitation residuals is the result of attempted reaction to situations beyond inherent capacity or is due to conflicting reaction tendencies and the inhibition of otherwise adequate behavioral discharge, it indicates a serious condition in neuromuscular homeostasis—an essential precursor of nervous breakdown.

Residual Load and the Plimsoll Mark. The concept of residual load covers unexpressed excitation effects left in the system after an attempted adjustment to stimulus displacement. It may be likened to an unexplored charge left in a gun after faulty firing. Presence of such residuals is indicated by a low R.Q. to a standard test excitation stimulus. Another indication of outwardly unexpressed tension residuals is their reappearance in a high basic energy level at subsequent periods of testing.

Sometimes excitation residual is only indirectly connected with a previous stimulation. That is, response may attain homeostatic equilibration, but be followed by re-excitatory effects, because of the felt discrepancy between the response and a socially approved standard of conduct. This was indicated by an experiment (53) on the effects of voluntary inhibition of micturition. Withholding this discharge gave low R.Q. values when pressure stimuli were applied to the bladder. But some subjects who withheld micturition for just a brief time and had good immediate recovery scores later showed residual effects. Publication of their comparatively poor performance in an open “with-

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holding contest" helped develop such re-excitatory effects. On the next day's withholding test such subjects returned to the experimental situation at a much higher basic energy level. Furthermore, because of very limited improvement, the re-excitatory effect again raised the basic energy level at the third period of testing.

In somewhat similar ways, we presume, continued attempts to resolve a frustration are paralleled by progressive build-up of residual effect until the habitual (basic) energy level approaches the individual's ceiling. Emotional rather than specific adaptive behavior predominates at such high levels and the system is dangerously near collapse and integrative breakdown.

We have here approached the most critical area in reaction dynamics. Other writers have spoken of the limits of "frustration tolerance," "adjustive capacity," "psychiatric danger zone," but none have yet found an adequate operational definition of such a construct. The present exposition attempts to link residual load to the limits of adjustive tolerance.

We can think of crucial stress and undischarged excitation as having loaded the patient's system with so many residuals that its habitual energy level is brought far above normal (the optimal reaction range). Discriminatory (rational) control processes are difficult if not impossible to re-establish on such a high level of energy mobilization, and so the system often goes into collapse.

What is needed is some test of the system's approach to its upper limits of effective operation before the progression has gone too far. Even better would be a test of how much residual load the system can carry without sacrificing homeostatic resiliency to new stimulus effects. This hypothetical safe loading level we have chosen to call a *psy-*

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chiatric plimsoll mark. The term is reminiscent of the line placed around the hull of a ship to indicate how heavily it may be loaded and yet retain enough surplus buoyancy to withstand the added stress of storms. It is proof of how much we have yet to accomplish in psychology that only the barest suggestion for such a test can yet be made. The day may eventually come when, as with the cardiologist's test of the safe loading limits for the patient's heart, we shall be able to predict the safe loading limits of the total reaction system in terms of R.Q. or of some other measure of residual effect from a standard displacing situation. Until that time, the construct of residual load will help point the search for measures of nervous breakdown point and the psychiatric plimsoll mark.

Tension Discharge Types. Up to this point we have avoided the common-sense use of the term "tension" as synonymous with nervous arousal. We use it now only because there is a presumptive connection between the tensions of nervous arousal and their covert expression in muscular tensions; that is, stimulus-induced sensory excitation tends to lead over to and discharge through motor processes which are already in a state of readiness tension, i.e., prepared for response. If one avenue of motor discharge, such as vocalization, is habitually favored over others, regardless of the type of displacing situation, we have a clear-cut example of a particular discharge type.

The steps which forced adoption of some such construct as *tension discharge type* are worth noting. Studies of set-expectancy brought the first realization that the basic energy level, the background met by stimulus-induced excitement, is not an unpatterned homogeneous affair (57, 112). Just as in overt response, it has a focus of heightened activity with resultant low thresholds in the reaction arcs

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involved. This is indicated by heightened electrophysiological activity and muscular tension in motor parts that the individual is set to utilize. When a sudden shock or startle stimulus is applied, the subject's focal overt reaction to the displacement is through the tense, prepared reaction part. If his vocal cords are "set" he tends to vocalize. If excitation in his leg muscles is already near threshold strength, he kicks. Even when a stimulus requires a special motor response discharge, as in pushing the key to signal a voluntary reaction, individuals differ in their ability to adopt the proper motor set. So called "sensory type" reactors have to be trained to develop new and more appropriate preparatory postures, whereas the already developed "motor type" adopts the special set with ease. People are trained to take particular preparatory postures for car driving, writing, and singing.

From these facts, it is but a short step to the hypothesis that *tension types* are also developed by conditioning techniques. Experimental proof of generalized preparatory postures is shown in many conditioning experiments, and much relevant clinical evidence is found in the habitual verbalizers, imaginers, and drinkers that crowd the psychiatrist's office. This type of evidence leads to the conclusion that some organismic energy systems become so structured by habit, their reactions to displacement favor a particular form of focal discharge, whenever this is at all possible. For example, some people seem to discharge aroused excitation by way of verbal discharge; whether it is an especially appropriate solution or not, they use this as a means to "blow off steam." Others use gross skeletal muscular action as the major avenue of discharge; in reacting to problems of increasing difficulty, such persons have been observed to hit the reaction key harder and

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harder or to engage in nonfocal movements of wiggling (77). Still others expel nervous excitement with their visceral organs, thereby developing somatic activity, and some discharge primarily on the ideomotor or phantasy level.

When an individual falls into a habitual pattern of energy distribution regardless of the kind of displacing stimulus involved, it would be proper to characterize him as a particular *tension discharge type*; this would mean that he tended to express aroused nervous energy through either skeletal, verbal, or ideomotor or somatic channels of activity. The term skeletal or *active-motor discharge type* has been developed to refer to a tendency to discharge aroused nervous energy through bodily movement, the term *vocal discharge type* for the tendency to use the vocal cords, the term *somatic discharge type* for the turning of nervous discharge inwardly through the visceral organs, the term *ideomotor discharge type* for funneling aroused energies through channels of phantasy and imaginative action. Presumably such clear-cut reactive types are the exception rather than the rule; the more normal energy distribution would favor any one of the four discharge types according to the displacement involved.

Determination of the relative predominance of different reaction tendencies or homeostatic discharge is approached in two ways: experimentally by measuring the relative pressure of antecedent and residual tension in different bodily parts under startle stimulation; clinically by obtaining evidence of the relative use of verbal, ideomotor, and skeletal behavior in discharging the tensions of daily living.

Little is definitely known as to which of the presumed discharge types provides the most adequate homeostatic response. There are several possible criteria. In the first

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place, the discharge has to be appropriate to amount and type of displacement. In the second place, it should be followed by little residual load. In the third place, it should be accomplished with the greatest economy of effort of input. All types of focal discharge can fill these requirements fairly well in some situations; but it may be that those of one type can fulfill all the requirements more adequately on the whole than any others.

The only way to answer the question of the relative efficacy of various discharge types is to make the actual comparisons. This is not practical under present research procedures, for type of tension discharge varies with the individual and with the displacing situation. It is commonly thought, however, that overt skeletal discharge and verbal behavior are more directly equilibrating than are visceral and ideomotor discharges. In fact, it has sometimes been assumed that internally aroused excitation tends most naturally to be expressed by overt skeletal discharge. If such means of reaction are blocked (and they are most subject to learned inhibition and control), some of the excitation tends to be deflected to the visceral and ideomotor outlets. Sherrington³ speculates on the relative adequacy of various channels for release of aroused excitation as follows:

Speech, since it provides some degree of externalization of energy, may be regarded as standing between musculo-skeletal behavior [motor action] and thought, and is also a manifestation of partial motor inhibition. The degree of availability of these modes of cortical expression to instinctual [arousal] levels is in direct proportion to the degree of motor inhibition, because of diminishing external risk, yet the degree of relief of instinctual tension depends on the degree of the sheer motor

³ *Brain*, 38, 217.

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component in the expression. Thus action gives the greatest relief, thought and phantasy the least. But uncontrolled motor action carries with it the gravest external threat and the least grave. Speech stands midway between them in regard to both considerations, and is thus a singularly happy medium of expression. The symbols, the phantasies with which the patient occupies himself represent a constant effort to translate the physiologic energies of instinct into a form adequate for cortico-spinal expression, or at least, into the dissipation of pure thought.

Special attention is called to the fact that Sherrington makes no mention of visceral activity as a type of discharge. This is correct on theoretical grounds, for such activity does not direct excitement outwardly. It tends instead to be self-perpetuating, and thus keeps the system upset rather than equilibrated. If Sherrington were writing today, he would doubtless indicate that psychosomatic disorder, such as peptic ulcer and tachycardia, is the presumed obverse of his three modes of expressive discharge.

It would appear that while some type of reaction might be habitually used for weak stimuli, a stronger displacement might cause a break-through to another type of tension discharge. Both stimulus intensity and basic energy level enter into the choice of reaction discharge. Possibly, some persons choose ideomotor discharge simply because they have little energy available to support more metabolically costly types of reaction. We are entering upon very uncharted territory here, for the whole idea of discharge levels and types involves the assumption of a reaction hierarchy for which we have, as yet, no comprehensive check.⁴

⁴ Clinical evidence on *change of symptoms* often indicates that inhibition of one channel of discharge causes another to appear. Thus a case of

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Principles of Response Discharge. From the foregoing sections and associated experiments, it is now possible to summarize the principles making for effective homeostatic discharge. These are (1) diversification, (2) specificity, (3) supplementation, (4) reactivation, and (5) moderation. A description of each principle and its application to total behavior energetics is given below.

Diversification is the principle of discharging aroused excitation through a variety of motor outlets. The previous section has indicated the average individual's capacity for considerable diversification in the type of tension discharge. While certain displacements may favor a verbal response and others a skeletal muscle movement, any and all channels of discharge are reasonably open to use as occasion demands. The more open all channels, the less restricted are the potential modes of homeostatic equilibrium. If vocalization is the focal discharge, background activity in the skeletal muscles may serve to work off excessive excitation and thereby maintain the focal discharge within its optimal range of effectiveness. Another value of diversified outlets lies in the fact that if one is temporarily closed off, another can take over and effect some equilibrium of stimulus displacement.

The importance of diversification in effecting equilibratory discharge is shown experimentally by studies that artificially restrict discharge outlets. A pig placed in a small box and given electric shocks became so unbalanced with undischarged excitation that it was rendered "neurotic." Placement in a box large enough to permit active motor discharging of stimulus-induced excitement made for more

uticaria showed that if *weeping* was forced by an aroused frustration, the skin condition failed to appear; the *uticaria* was one expression of unreleased tensions and weeping represented a substitute type of discharge.

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rapid equilibration and lessened residual load. Pavlov likewise restricted response discharge to help produce experimental neurosis in the dog. And when human subjects undergoing shock stimulation are tied to a cot and prevented from making writhing and vocal responses, R.Q. is diminished (79). Furthermore, there is abundant clinical evidence that as the number of potential discharge outlets is increased (by removal of inhibitions, fears, etc.) equilibration of stimulus-induced effects is more easily accomplished.

Specificity is the principle of discharging aroused excitation through the part-reaction outlet most specifically appropriate to the irritating condition. We have already indicated the operation of this principle in our treatment of the patterning of response discharge. Therein we mentioned that the ratio of focal to background discharge provides a means of differentiating efficient from inefficient homeostasis. We restate the principle here mainly to emphasize that mere quantity of discharge does not alone make for effective neuromuscular homeostasis. Quality counts too. Use of a particular channel of discharge that effectively changes his relation to the stimulus displacement marks the subject as a *specific adapter*. Other things equal, his R.Q. is higher than the *nonspecific adapter* who discharges the same quanta of aroused excitation diffusely or through relatively inappropriate behavior.⁵

⁵ It appears that learned inhibition of a specific discharge outlet operates largely after the response pattern has approached the overt level. We find an epithet on the tip of our tongue and just barely keep our mouth shut. Specific overt discharge usually appears at the peak or slightly after the peak of the general homeostatic response curve. Not until such response develops a degree of overtness can it be inhibited and hence prolong or prevent recovery in the general energizing activities of the organism. The relation between covert and overt response can be stated as follows: When

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The homeostatic superiority of specifically adaptive, appropriate part-reactions over those which are generalized, inappropriate, or all-over-the-place has been shown experimentally in a number of ways. Criminals under examination and candidates for acceptance to college had to give answers to brusque personal questions and at the same time to signal by pressing a key (105). Those who channelized aroused energy most specifically through straight-forward answers and pressing the key as directed recover equilibrium more rapidly than those who tried to lie and who let their energy leak off through unrelated acts such as trembling, pressure in the idle hand, facile twitches, etc. Grade-school boys (69), playing a slot machine game for candy awards, who took out their disappointments by whacking hard on the reaction lever recovered equilibrium more rapidly than did the nonspecific adapters who made general restless movements. Women typists (2) working under gradually increasing pressure behaved in two general ways; some specific adapters hit harder and faster on the key, turned out more work, and ended the ordeal less exhausted than others, nonspecific adapters, who took out the increased excitation by tapping their feet, wagging their tongues, and wiggling in their seats.

The need for training men to employ specific response foci for the discharge of stimulus-induced excitement is well recognized in military training. By emphasizing one type of discharge, such as firing a gun, through constant practice a readiness is created to use these foci under any

a subject in a resting condition is displaced by an adequate stimulus, tensions of reinforcement resulting from that stimulus mount to a point at which they are expressed through some overt activity. Blocking of one activity at the overt level may be followed by diversion of the unexpressed excitation to other channels of outlet.

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and all conditions. Thus the trained specific adapter will discharge the emotional arousals of actual combat appropriately where they will count, whereas the untrained nonspecific adapter will tend to dissipate similar arousals in generalized flight or fear reactions that leave him a prey to nervous exhaustion or the enemy.

Clinical data indicate that it is always more physiologically relaxing to react to frustration as directly as the situation will allow. This includes talking back politely to the boss rather than raving about mistreatment to friends, taking up a job that has to be redone rather than crying over it, concentrating on improving a necessary skill rather than trying to get in another person to help out. In any nonspecific discharge channel used with favorable consequences, analysis will usually show the effect is produced by supplementation not substitution for the specifically adaptive focal part-reaction.

Supplementation is the principle of discharging some of a quanta of aroused energy through accessory (background) outlets. Its special value appears when the specific focal discharge outlet cannot conveniently expel the total energy arousal. Recognition of this principle has already been implied in studies of performance at high energy levels. One experiment showed that tics (77), motor automatisms, and wiggling during electric shock stimulation helped maintain the flow of energy transformation through a specific voluntary reaction arc within the range of optimal effectiveness. Further proof comes from experiments wherein gum chewing (91) and foot tapping (60) were shown to discharge considerable excitation during examinations and protracted mental work, thereby increasing total homeostatic equilibrium.

The principle of supplementation neither cancels nor

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counteracts the principle of specificity. Its special value is its use in combination with appropriate focal discharge to affect total expulsion of aroused energies. It is a safety valve for expelling excess energies whose continued operation fogs up and beclouds the specific channeling of response discharge. Supplementation must always be through background part-responses. The moment any nonspecific supplementary response becomes extreme, it may become focal to behavior, provide a fresh distraction, and so defeat its purpose. For example, humming may help a person hold himself down to a job of writing; but if he becomes so engaged in the humming that he forgets his writing, negative rather than positive value will be achieved. This, of course, takes the person almost completely away from specific adjustability to the stimulus displacement and may render necessary the use of another principle to force return.

Reactivation is the principle of discharging residual load by a return to situations originally producing the unbalance between arousal and discharge. Whereas the three foregoing principles have centered on the most effective continuance of a reaction sequence already in progress toward equilibration, our fourth principle deals with restating a sequence that has failed to attain complete homeostatic discharge. It involves the conversion of excitation residuals, due to blocked or ineffective reaction, into stimuli that get the organism started back into the originally exciting condition. Therein the subject makes a fresh attempt to discharge excitement through more specific channels than formerly.

Reactivation is a technical way of saying "if at first you don't succeed try, try again." It means that residual load is to be released and lasting recovery best effected by

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reactivating a fresh start at direct specific motor discharge rather than by circumventing action, developing around the situation abnormal fears and imaginary solutions. The operation of the principle has been shown experimentally in the forced feeding of neurotic cats who had developed residual food phobias and in the forced flying of pilots who had lost their nerve as the result of a crash. These are both illustrations where special outside help was used to reactivate. In most situations, however, the energies from residual load can be self-reactivated toward the original displacing situation rather than away from it. Of course, there are limits in that reactivation may not always bring a more specifically adaptive homeostatic discharge. Excessive "rebucking" of an impenetrable barrier will create instead of reduce residual load. Here, as with the operation of the other principles of response discharge, moderation is in order.

Moderation is the principle of discharging aroused energies over a middle reaction range. An earlier section has emphasized the importance of maintaining a median level of energy mobilization—as with the arousal so with discharge. Overt reaction has to be set in relation to the amount of arousal; underreaction or overreaction makes for ineffective homeostatic adjustment. Underdischarge fails to expel sufficient aroused energy and leaves residuals. Overdischarge re-excites the system by excessive backlash action and thus also creates a residual load. Many experiments confirm or corroborate this statement of the golden mean of reaction. Just as high energy arousal due to rapid work pacing (114), sustaining heavy weights (48), and work for high money incentives (62) produces a preponderance of nonspecific, generalized emotional responses in all subjects, so a median arousal level results in similar effects for

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those individuals whose R.Q. showed they overdischarged and underdischarged (67).

From Physiology to Psychology. The above principles, derived mainly from physiological experiments, can have a much wider usefulness. We have in neuromuscular homeostasis a basic principle that puts a biological floor under much of current psychological thinking. The use of covert indices of energy transformation provides an objective methodology for investigating complex behavior phenomena, such as motivation, learning, discriminatory and non-discriminatory adjustments, personality differentiation, and the behavior disorders. Finally the topics discussed in this chapter supply gap-bridging physiological constructs that are offered as substitutes for the psychic energy constructs that have beset dynamic psychology since the time of Freud.

Motivation

A New Approach. Modern psychology's interest in why human beings behave the way they do centers around the discussion of two major topics, motivation and learning. An intimate connection between motivation and learning factors is always presumed, but experimental and descriptive approach varies according to where emphasis is placed. When ramifications of inner motive are the chief concern, we get the approaches of psychoanalysis and topological psychology. When behavior modification by external stimulation is considered paramount, we get the approaches of conditioning theory. A fundamental liaison between the opposed viewpoints is best achieved not by arguing conditioning facts into psychoanalytic terms, or vice versa, but by attacking both topics from the deeper level of homeostatic analysis. Psychoanalysts will recognize the fundamental connection between organismic equilibration through action and their psychic energy constructs, while exponents of conditioning theory will appreciate the opportunities afforded for objective check of inner reaction dynamics.

The present chapter deals with motivation. In extending homeostatic principles to this highly complicated field, many gaps in treatment will appear. Wherever possible we shall give experimental evidence and concrete illustration. Elsewhere our only present recourse will be to mention

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the covering construct and to point up the problem for future research.

Inner and Outer Control of Behavior. In many accounts of motivation, the self-preservative functions of the total organism are described in either of two ways: (1) Since the basic cause of reaction is an internal change, all higher-order behavior may be viewed as *forced from within*; or (2) since internal disequilibrium is intimately associated with external change, all higher-order behavior may be regarded as *conditioned from without*. Both interpretations are, of course, an oversimplification of the problem of control, and neither can be applied alone to all homeostatic adjustment. Those behaviorists who are preoccupied with linking outer responses to outer stimuli often go enormously wrong, as when they associate a fear reaction with a loud noise, only to find out later that the subject did not hear the noise stimulus, but was thinking of something else. Similarly, the psychoanalyst who is preoccupied with linking conscious behavior to remote internal conditions will often erroneously associate the presence of a toothache with an unconscious desire to escape thereby from some other behavior. Once a stimulus-response psychologist gets the immediate cause of behavior inside the skin and once the psychoanalyst makes sure that his alleged inner forces are actually present, a fundamental source of disagreement disappears.

Yet this is not enough. It would still be possible to speak of the organism as "adjusting" more to an inner stimulus change at some times than at others. In the developing organism, behavior is at first directed largely to equilibrating disturbances of the digestive-circulatory system. Later, as energy stores become sufficient to maintain the superposed neuromuscular system in a heightened state of vigi-

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lance (*basic energy level*), a sensitivity to the external environment is maintained. We have already mentioned that the waking level of energy mobilization is habitually higher than the basal values needed to maintain life (page 114). Thus is the organism "alerted" to external stimuli that are potentially harmful or beneficent to its internal constant states. Furthermore, the specific residuals of former stimulus-conditioned reactions of the neuromuscular system develop "set-expectancy" for particular types of internal change (principle of backlash action). So far is this development carried in the adult human organism that the importance of internal disequilibria in the maintenance of essential constancies is all but lost from view. We need to be reminded occasionally that the sight of water does not lead a man to drink unless he is thirsty, and that some degree of internal disturbance must be operative before the mere presence of a mate leads an animal to make sexual advances.

The efficacy of an external stimulus is determined by the condition of the response apparatus itself; whatever reactions are actually made are the ones most ready and available and not those the stimulus necessarily calls for. This was experimentally demonstrated when instructions shifting anticipatory tension from arm to leg muscles produced overt leg reaction to a stimulus normally calling for arm reaction (45). Similarly, reaction to mathematical symbols is altered when the subject is mainly aroused by an undischarged micturitional tension (51).

All this suggests the necessity for affirming the priority of internal conditions and essential constant states in the ultimate direction of behavior. A man can respond to minor external displacements only as his internal disturbances are adequately reacted to and equilibrated. There is little

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expectation that a hungry person will stop his search for food to admire the sunset. Furthermore, the overt behavior allegedly produced by an external stimulus has a way of being associated, though ever so subtly and remotely, with other and more essential internal disturbances simultaneously operative. For example, a mild degree of experimentally induced micturitional tension may actually reinforce and speed up higher problem-solving activity, whereas greater amounts of such undischarged excitement will inhibit the superposed and outer-controlled performance (optimal reaction range) (46). Conversely, the spectator at a ball game may think of himself as responding solely to the play of external stimuli, but the fact that he expends energy all out of proportion to such arousal makes it appear that he is actually discharging a great deal of pent-up excitement held over (as residual load) from some other situation.

Division of Labor in Motivated Behavior. While we can say that all total behavior is motivated at least in the sense of relieving some organic displacement, there are distinctions as to level and type. The field covers everything from automatic regulation of materials and processes of the internal environment to learned regulation of materials and processes of the external environment. Such diverse operations are accomplished by a division of labor in neuromuscular homeostasis. According to broad outlines of function, there are two great divisions. The first acts inwardly on the hollow viscera and glands of the digestive-circulatory system and thus governs the internal environment. The second acts outwardly in relation to the external environment.

If we think of the first division only in terms of its *neural control* centers, we call it the *autonomic nervous system*;

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when the kind of effector tissue (smooth muscles and glands) whose action it regulates is also included, the division is referred to as the *interofective system*; if the type of focal behavior which it promotes is distinguished, the division is called the *general emergency (emotional) reaction system*.

Concerning the second division, related labels may also be attached. If this division is considered only in terms of its nervous control we call it the *cerebrospinal* or *central nervous system*. When the kind of effector tissue (largely striated muscles) whose action it regulates is included the division is called the *exteroffective system*.¹ And if the type of focal behavior which it promotes is distinguished, the division is called the *specific adaptive (perceptual) reaction system*.

This definition of terms will be helpful in describing these two systems of homeostatic control in motivated behavior. We shall begin with the simplest instance of interofective regulation and proceed to the most complicated levels of exteroffective regulation, always keeping in mind that the total dynamic maintenance operation is a product of interacting bodily parts.

Interofective Homeostatic Regulation. Our illustrations of interofective homeostasis will be confined mainly to two types of internal need: (1) fuels for essential metabolic activity and (2) oxygen conditions needed to burn them. Both instances involve the conjoint but antagonistic action of the two subdivisions of interofective autonomic control, the sympathetic and parasympathetic nerve centers. We shall see that these act as do the elevating and depressing

¹ This designation has the sanction of Cannon, Sherrington, and many other physiologists. Kempf has called it the proficient system, because its superposed functions are over the autonomic system of behavior controls.

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mechanisms of limited organ homeostasis to maintain total emergency adjustments within proper bounds (optimal reaction range).

The interofective system's maintenance of an essential concentration of fuel in the blood stream is best illustrated by the homeostasis of blood sugar. The normal oscillation in the concentration of sugar in the blood occurs within a relatively narrow range of 70 to 130 milligrams per cent. Probably these ups and downs are produced by the imperfect balance of opposing factors, one group depressing, the other elevating, the glycemic level. The elevating tissue activities are primarily under control of the sympathetic nerves, and the depressing activities are controlled largely by the parasympathetic fibers. When bodily tissues make heavy emergency demands on blood sugar in carrying out their needed metabolic activity, the glycemic level begins to drop from its average 100 milligram per cent level to 70 milligram per cent or below. This induces a "hypoglycemic reaction" in which sugar-sensitive receptors excite the nerves to release sugar from the stores segregated in the liver. Another part of the hypoglycemic reaction is the rapid pulse (due to need for more rapid pumping of blood fuels to active parts of the organism), and the increased secretion of adrenalin, the latter acting humorally upon muscle and liver cells to increase the available fuel supply. If these elevating mechanisms are unable to bring forth sufficient sugar from body stores, the glycemic level falls from 70 to about 45 milligrams per cent (the margin of safety), and serious convulsions may ensue. This threatening condition seldom becomes operative because an abundant store of glycogen is maintained by way of the hunger mechanism and the exteroffective feeding behavior it develops.

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The presence of excess sugar in the blood stream is almost as serious a threat to the integrity of the organism as is hypoglycemia, and here parasympathetic control centers, acting through the vagus nerve, depress the activity of organs that would release sugar from body stores and aid in the process of further storing. The first temporary deposit of excessive blood sugar is by inundation or simple overflow into the skin. Later there is a change in the molecular configuration with the aid of the islet cells of the pancreas, and the sugar is stored by segregation in muscles and the liver. If this vagoinsular depressive mechanism is ineffective, the glycemic level rises from 130 to 180 milligrams per cent and sugar begins to be lost through the kidneys rather than used or stored for fueling the body activities.

Thus the management of the glycemic percentage of the blood within optimal limits is accomplished by antagonistic interofective neural mechanisms, acting in conjunction with the humoral control over limited organ system homeostasis. It is probable that variations in the amount of other essential metabolic materials are as carefully regulated.

The maintenance of an adequate oxygen supply is vital to all cells of the body, but because it is everywhere present in the external environment, storage (as with body fuels) is unnecessary. The oxygen demands of various states and degrees of vital activity vary considerably. In order to burn up the rapidly accumulating waste products of vigorous muscular exertion, an oxygen intake more rapid than in the state of quiet rest must be attained. Homeostasis in this situation is achieved automatically by interofective regulation of the speed of the continuous respiratory process.

This is accomplished in the following manner: assuming

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a ratio of oxygen to carbon dioxide (O_2/CO_2 tension) in the blood equal to average demand as a starting point, excessive activity of bodily tissues causes oxygen to be used up more rapidly than its intake; as a result, the oxygen of the blood falls and its CO_2 content increases. As this blood is diffused over the nervous system, specially sensitized cells in the "respiratory center" of the *medulla oblongata* respond to the change in O_2/CO_2 and discharge nerve impulses to the muscles of respiration, so that their action is more rapid than before. This causes an increased rate of oxygen intake by the blood. When this has continued to a point of reducing the O_2/CO_2 tension to a ratio essential for the normal level of vital activity, the extra stimulation of the respiratory center is removed and quiet breathing is resumed. While the exact mechanisms by which the respiratory rate is governed are not yet known, it is presumed that increments during emergency are due to sympathetic interofective processes acting to elevate the breathing rhythm, normally "depressed" by parasympathetic processes.

This is not the full extent of the marvelous bodily economy which insures an adequate oxygen supply. Although an increase of only 0.22 per cent of the carbon dioxide in the alveolar air will cause a 100 per cent increase in respiratory ventilation, during highly strenuous work more oxygen is needed than can be supplied immediately under the most favorable respiratory conditions. Thus it becomes necessary (1) to develop all auxiliary aids to rapid ventilation of carbon dioxide, and (2) to develop means by which the immediate need for oxygen is temporarily offset. In the first instance sympathetic nerves act in conjunction with adrenalin liberated into the blood stream to speed up circulation; heart action is increased, the arterioles and capillaries in active muscles as well as the bronchioles and

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alveoli of the pulmonary system are relaxed, and added red corpuscles (the carriers of carbon dioxide and oxygen) are released from the spleen. In the second instance, the accumulating lactic acid, for which there is not sufficient oxygen available for immediate burning, is temporarily neutralized so as not to disrupt another constant state (the acid base relation), and its final burning is accomplished after the violent exercise has ceased. Thus the organism borrows the ability to work for a time beyond the limits set by available oxygen, and discharges its "oxygen debt" by taking in additional oxygen after the strenuous activity has ceased. Much more could be added concerning the complex interactions of parts which produce oxygen homeostasis, but the broad outlines are already clear. Beginning with essential tissue activities held under "depressive" control by parasympathetic centers, during conditions of quiet rest, the sympathetico-adrenal interofactors perform their elevating functions automatically and in proportion to emergency demands. Complicated as the system may be, the basic homeostatic description emerges; namely, the tissue need (oxygen) causes its own remedy.

Integrity of the organism's constant states is threatened not only by fuel and oxygen deficiencies but also by untoward external conditions such as the approach of a natural enemy. Psychologists have made elaborate studies of the general emergency reactions by the interofective system, which prepares the animal for flight or fight. The mechanism by which this is accomplished does not differ in essentials from those already described. The threat stimulus causes an upset of the internal milieu, exciting the sympathetic center of the thalamus to gain temporary ascendancy over parasympathetic controls. There is emergency release of adrenalin into the blood stream which

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acts with the sympathetic reaction of the autonomies to increase smooth muscle and gland activity. This increased energy mobilization (A.I.) carries over into overt rage or fear movements of the skeletal muscles (D.I.) until the organism either removes or is removed from the threatening external situation and internal harmony (R.Q.) is again restored.

From Interofective to Exterofective Regulation. We have now reached a critical point in our treatment of motivation, for the line between behavior integrated through interofective and exteroffective systems cannot be sharply drawn.

Maintenance of an adequate oxygen supply would seem to be essentially an interofective affair, automatically regulated and making no demands upon the central nervous system and the overt behavior of the general skeletal musculature. This is almost the case, due to the everready presence of oxygen in the external environment. There are occasions, however, when there is blocking and frustration of the basic respiratory function (as in smothering or when the oxygen content of the atmosphere has been critically lowered at high altitudes). In these instances the exteroffective system is stimulated to make a final stand against the change which threatens organismic integrity. The baby writhes and flays the air with its arms to escape from a smothering blanket and the person who is having difficulty with breathing at high altitudes either lies down, thus decreasing the oxygen demands of muscular exertion, or else executes a series of learned movements that will supply needed oxygen from a tank carried along for this possible emergency.

The maintenance of other essential constant states, such as food and water balance, is much more dependent on

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exteroceptive interference at critical times than is the case with oxygen homeostasis. The reason is obvious. Water and food are not freely present in the external environment of most organisms and particularly in that of man. Consequently, no interobjectively ruled mechanism such as respiration would alone suffice. Water and food needs must be received in overabundance when they are available, and before they become exhausted a condition must supervene whereby the organism again makes contact with necessary supplies in the external environment. The exteroceptive system has been developed to serve this contact function, but it is tied to the interobjectivity system by inseparable bonds.

In the previous sections, the tacit assumption has been that fuels and other maintenance needs were already present within or easily available to the organism. The humoral controls of limited organ functions and the neurohumoral controls of the interobjectivity system operated to elevate or depress withdrawals of energy stores as occasion demanded. Now, through very specific and very local mechanisms, such as stomach contraction, throat dryness, and intestinal pressure, the exteroceptive system received rather nonspecific compulsions to general skeletal activity, some portion of which behavior may provide the essential condition for alleviating the original disturbance.

Thus, long before smooth muscles and glands reach harmful conditions of excess or deficiency² not cared for by their autonomic controls, these tissues have developed internal stimulating conditions that act through the central nervous system to excite overt skeletal behavior

² The reason for this is obvious; exteroceptive behavior must not supply internal needs so abundantly that storage mechanisms will break down, nor must the internal store become so exhausted that the organism lacks strength to carry out the often elaborate behavior needed to assure a new food supply.

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calculated to restore the basic disequilibrium. The mechanisms of hunger and thirst are the most notable examples of this class of internal disturbance requiring exteroffective homeostasis. And if we include the maintenance of species identity through reproductive behavior as an essential organismic constant, sex needs also fall into the same category.

It is well to examine these transitional mechanisms with reference to their interofective precursors and their exteroffective consequents. The internally developed appetites for food, drink, and sex partners arise through failure of the interofective system to maintain homeostatic balance beyond narrow limits; and such overt behavior which appears at first glance to be oriented with reference to the external controls is actually built upon these internal needs.

It seems very reasonable to assume that all the complicated adjustments to external stimuli as well as all creative efforts of man are fundamentally associated with the maintenance of essential steady states of the fluid matrix of the body. This account differs, therefore, from Cannon's, which holds that the interofective control of body homeostasis frees the exteroffective system for other and unrelated processes. To quote: ³

Insofar as our internal environment is kept constant we are forced from the limitations imposed by internal and external agencies or conditions that could be disturbing. This is chiefly freedom for the activity of the higher levels of the nervous system and the muscles which they govern. By means of the cerebral cortex we analyze experience, we move from place to place, we build airplanes and temples, we paint pictures and write poetry, or we carry on scientific research or make inventions.

³ Reprinted from pp. 284-285 of *The Wisdom of the Body* by Walter B. Cannon, by permission of W. W. Norton & Company, Inc. Copyright 1932 by Walter B. Cannon.

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. . . The alternative to this freedom would be either submission to the checks and hindrances which disturbance of any constants of the fluid matrix would impose upon us; or, on the other hand, such conscious attention to storage of materials and altering the rate of bodily processes, in order to preserve constancy, that time for other affairs would be lacking. It would be like excluding foreign relations because of troubles in the interior. . . . In summary, then, we find the organism liberated for its more complicated and socially important tasks because it lives in a fluid matrix which is automatically kept in a constant condition.

The paragraph above reads very much as if the "body" freed the "mind," but this is probably not Cannon's intent. No such question need arise if the statements are interpreted only to mean that the exteroceptive system is relatively free from the details of internal maintenance operations. Its activity always is bound up with homeostatic equilibration, and it is essential to the maintenance of organismic identity both as an advance guard and a last ditch defender to the essential steady states.

In higher organisms, such as man, increasing dependence of the internal steady states upon variable external factors has necessitated the development of a most elaborate adaptive mechanism, the exteroceptive system. Through it the organism is enabled to make conditioned reactions far in advance of its immediate internal needs. Furthermore, when there is malfunctioning or organic disturbance for which no "natural" homeostatic equilibration can be supplied, the exteroceptive system will initiate a most extravagant series of behaviors in an attempt to restore internal equilibrium. That a case of spastic paralysis can lead either to the creation of great poetry or to a persecution complex is well known in clinical circles; yet both behaviors are homeostatic-regulatory with reference to

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the same basic displacing condition. Another outcome of the increasing prominence of exteroceptive controls in higher organisms is the frequent conditioning of some internal disturbance to chance external stimuli that happen to be simultaneously operative. Clinical literature reveals many instances where the adequate equilibrator for an internal disturbance takes a bizarre form, such as a hand-washing compulsion to quiet hunger pangs.

External stimulus situations have a way of producing more profound disturbance in some individuals than in others, the differences apparently due to a deeper level of conditioning. In experimentally induced frustrations of problem solving in children, it has been found that failure following outstanding initial success is more fundamentally disequilibrating (higher A.I.) than is failure following little or no success (69). Furthermore, individuals showing the more intensive and extensive physiological disturbances tend to work harder to avert failure and achieve success in spite of frustration. Similar deductions appear to be appropriate from a study of individual differences in the completion of interrupted work (44). Such experiments even suggest that the age-old question of "who is the most motivated" can eventually be answered in terms of either arousal (A.I.) or some measure of the amount of blocking an individual will take before being turned aside from carrying through an act-in-progress.

Certainly clinical evidence would support the verdict that only as one's ideals and aspirations get located in his viscera (somatic type of reinforcement) will the person be highly motivated to act upon them. This is saying in effect that only because his internal processes are abnormally displaced does the martyr willingly die at the stake rather than retract his heresy; physical death is here more home-

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ostating than is continued existence under the tension (residual load) of the hypocrite.

Internal Needs and Exterofective Regulation. We have already indicated that the exteroceptive system functions both as advance agent and rear guard in homeostatic adjustment, with the interoceptive system carrying on within these limits those automatic maneuvers which maintain organismic identity. In illustrating how exteroceptive behavior protects essential interoceptive operations, the hunger mechanism provides a good example. Long before the stores of fuels are depleted within the body, the exteroceptive system is stimulated to behavior calculated directly or indirectly to assure an abundant replenishment by materials taken from the external environment. The dynamics of this total reaction sequence are well known. In the absence of food in the stomach, acid secreted from certain cells in its walls acts directly on these walls to increase their rhythmic contractions. Increased stomach contraction results in increased excitation of the central nervous system (principle of backlash action). This leads over into general skeletal movement, which tends to persist until some specific motor discharge results in the taking of food into the stomach. This in turn causes the irritating stomachic condition to subside and the exteroceptive feeding movements which accomplish this reduction in energy mobilization (D.I.) become fixated for later economy of effort.

The perfection of basic need behaviors such as feeding movements and their conditioning to external stimuli is a basic learning operation and will be treated in detail in the next chapter. Our present interest is to establish the general process by which the advance guard action of the exteroceptive system is initiated and equilibrated. Experiments (141) have shown that hunger contractions of the

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stomach coincide with elevation in the general activity level. The general arousal increment (A.I.) is roughly proportional to the intensity of hunger contractions, and the discharge decrement (D.I.) is associated with overt focal part-reactions that connect the organism with the source of food. There is also evidence (40, 138) that the entire food-taking operation functions best when the total system is midway between starvation and satiety (optimal reaction range).

Just as exteroffective behavior functions as an advance agent in homeostatic regulation, so in many cases it is also able to direct a last ditch stand against forces which threaten organismic integrity. As lower order autonomic controls break down, there is still appeal through the action of higher nervous centers. Experimental and clinical evidence for this statement is rapidly accumulating. For instance, the parathyroids normally act in conjunction with interoffective nervous control to regulate the amount of calcium needed for metabolism. If these glands are removed, however, the organism actually begins to "seek" for free calcium salts in the external environment. Animals without parathyroids will compensate for the breakdown of interoffective regulation by going long distances in search of rock salt (122). Their taste sensitivity to calcium is increased as much as sixteenfold (as shown by discrimination tests), and associated exteroffective behavior is directed to putting needed chemicals into the blood stream when the attachment of calcium stores in the bones is made impossible by removal of the interoffective control mechanism (123).

An even better instance of exteroffective rearguard action in motivated behavior is provided by experimental removal of the adrenals. Absence of autonomically released

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adrenal secretion in the blood stream makes it impossible for the islet cells of the pancreas to store blood sugar. But the presence of abnormal amounts of water in the body will help expel the sugar excesses through the kidneys. Consequently, in order to remain alive, the adrenalectomized animal will seek and drink water in excess. A clinical case is on record which indicates the same effect. A boy was sent to the hospital for observation, and while there begged for water all the time. Not enough was given him and he died. Autopsy showed defective adrenals. The water craving⁴ and associated exteroceptive behavior had apparently developed to compensate for the defects of interoceptive homeostasis.

At present we have only scratched the surface of that vast territory of endocrine interrelations and associated behavior. Experiments clearly show a compensatory increment in sensitivity for phosphorus, salt, sugar, and other essentials of metabolic regulation that have been interfered with by glandular removals (122). General energy mobilization (A.I.) is heightened and overt behavior is directed to equilibrating the need. If the need is not supplied by feeding, the internal nervous disturbance persists (residual load). The suggestion that this may be the basis of many food cravings, as in pregnant women, deserves careful study.

Exteroceptive Regulation and the Created Need. Whereas our illustrations of motivated behavior have heretofore dealt with processes by which the organism maintains or protects essential internal constancies through attachment

⁴ Lest this suggest that all appetites can be referred directly to internal needs and defective homeostasis by lower order mechanisms we should read that Young (*Psychol. Bull.*, **38**, 129-164, 1941) has found that habit is also a determinator.

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of or withdrawal from external agents and supplies, now we shall see that higher organisms at least tend to maintain constant states outside the body as well as inside. This is especially true for any external condition which—ever so remotely—will anticipate tissue needs or contribute to undisturbed functioning of internal constant states. The paramecium maintains a beneficent external environment only by migration through food-laden waters. But man, faced with similar needs, improves upon the paramecium and maintains a superabundance of food (or the means of ready excess) directly about himself. His motivated overt activities serve to maintain in the external environment not only a constant supply of food on the pantry shelf, but also the bank account, shelter, union membership, or circle of friends which are safeguards against potential external threats to internal constancies.

We are justified in taking this egocentric view, which says in effect that man conceives his world; for in the interests of preserving internal constancies, the exteroffective system develops and maintains optimal external constancies. By means of overt reaction to specific external stimuli the human organism stabilizes and betters its surroundings, eliminates potential dangers, acquires a surplus of commodities and tools, and establishes the set of habits which constitutes an individual version of the “margin of safety” need to maintain identity.

From our point of view these self-constituted surroundings *are* the organism, and the behavioral processes by which they are maintained are homeostatic-regulatory. This is to say that a slander is just as much a threat to a man’s good name—built up by a series of elaborate exteroffective behaviors—as is a change in oxygen supply a threat to essential life processes. The organism will react to both

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displacements with behavior calculated to restore balance and equilibrium. The only difference in the two examples is that the "good name" constancy is not nearly as stable and universal as is the oxygen requirement.

True to homeostatic principles, the organism does little to restore or order its external environment until that environment through its deviation from optimal conditions does something that jeopardizes internal constancies. Then the "threat" is met by increased general energy mobilization (A.I.) and an overt discharge, not necessarily most appropriate, is made to reduce the nervous tension (D.I.). The lowest-order equilibratory behavior to threatening external change is an escape reaction with predominate autonomic control. Though it may equilibrate the organismic disturbance (satisfactory R.Q.), this behavior changes the hostile environment not at all. It is about the only means of equilibratory total behavior possessed by lower organisms. But higher mammals, by virtue of better-developed central nervous controls, are provided with the potential means of distorting their external surroundings so as to maintain a greater margin of safety. Thus the rodent digs a hole in the ground, within which limited but relatively constant external environment he is reasonably safe from his enemies. He resorts to low-order escape reactions only when his self-constructed external constancy becomes insecure.

Even in man, whose exteroceptive system has the greatest capacity to mold the world to his internal needs, autonomic emergency reactions often take over, especially when external conditions have forced energy mobilization beyond the level favoring the optimal reaction range. The resultants of this nonspecific, emotional behavior are hatred and greed, violence and war. Men run from burning buildings like untamed animals when a careful extinguishing of

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the fire would serve better their long-time higher-order homeostatic interests. Our history books recount man's difficult climb toward the building of long-term specifically adaptive safeguards against possible harmful conditions in substitution for short-term general emergency adjustments. In that shift from autonomic to cerebral dominance of externally oriented behavior lies the basis of all altruistic action.

Freedom for Altruistic Action. Broadly enough regarded, it seems that all higher-order exteroffective behavior, including so-called altruistic acts, is inextricably bound to personal interests and culturally developed needs. We have already seen that the human energy system maintains the cerebral centers in a state of vigilance toward external stimuli, thereby providing for the more lasting satisfaction of basic needs by the development of long-term adjustments. As men must live in groups and would harm each other through the unbridled exercise of short-term homeostatic adjustments (as in emotion), appeal is made to previously developed codes of social conduct and new members of the group are conditioned to their acceptance. Beyond this, some individuals with greater freedom from specific internal needs and enough general alertness to be challenged by complex stimulus relationships develop new and creative reactions which are of ultimate betterment to the long-term homeostasis of all men. In this sense, we speak of the labors of the scientist as altruistic, even though their original source may be the same needs that produce the drunkard.

Both short-term "selfish" and long-term "altruistic" reactions have evolved progressively. The latter, however, have gained on the former with the growth of the cerebrum and our cultural heritage. Altruistic actions seem to flower most

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readily in those individuals whose essential needs are neither so completely satisfied as to render them complacent and unresponsive to the potentialities of unique modes of adjustment, or so completely unsatiated that all their energies must go into the low-order "dog-eat-dog" struggle for existence. Since general energizing processes can be directed to sustaining either an internal need or an alertness to external stimuli, creative work and responsiveness to impersonal stimulus relations appear to best advantage when the organism is maintained at a point between the extremes of complete satiety and complete hunger for its basic needs (optimal reaction range). This is one reason why creativity—the capacity to select and arrange—does not commonly flower in either the desperate poor or the complacent rich. It also suggests that, other things equal, the persons most capable of directing community living are those who are secure enough as individual energy systems to have some freedom for higher-order adjustment, but are yet insecure enough to sense the need for improving the environmental constants and socioeconomic conditions of all men.⁵

It would be a mistake to assume, of course, that freedom of action necessarily implies that all exteroffective behavior

⁵ R. W. Gerard (*Phil. Sci.*, 9, 101, 1942) has pointed out that objective science must deny the validity of any ethical practice derived from revelation. "Not only do lay friends nose out by nebulous cues of work and act, a man's character," he says, "they know how to discount his avowed description of himself and his motives." Moreover, the trained psychiatrist, with the full complement of objective methods, "can reveal most clearly the biological springs of deep convictions and compelling desires." An individual code of morals cannot serve as a sound basis for group ethics unless the ideal is one shared with the majority of mankind. Men become conditioned to the advantages of long-term cerebrally dominated adjustments over short-term homeostasis of lower order. So private morals are mostly derived from public morals, which have become "internalized by learning."

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will be oriented in the direction of improving man's estate, or that it will even bear a predictable relation to internal needs. Some tissues, particularly the endocrine glands, serve a general energizing function and maintain the central nervous system at a high vigilance level. If there are no specific needs which must be immediately met and sensitivity is relatively high, the adjustive system is relatively open for reaction to any minor external stimulus displacements—beneficent or noxious, as the case may be.

Habits as Drives. Psychologists have long recognized that when externally oriented behavior is practiced long enough, the habit may create its own need for continuance. In such cases of "functional autonomy" a habit can become a drive through reinforcement by more basic internal displacements. Thus one might first drink alcohol or smoke, not from any real need for these activities or as an escape from other displeasing conditions, but because he happened to be free to react to their presence in the environmental field. Later, if the practice were sufficiently repeated, the reaction would disequilibrate more basic constancies of the internal milieu, and be met by the development of compensatory reactions, including antitoxins. Finally antitoxins or other response residuals would build up sufficiently of themselves to constitute a disequilibrating condition; the habit becomes a drive as the organism begins actively to seek the conditions which will relieve the developed craving. In ways less understood, any activity, such as playing golf or cards, can pass from an occasional play response, when the organism is relatively free from basically motivated work, to a persistent compulsion satisfied at considerable effort. No one has any precise idea about how much the repeated performance of apparently nonadaptive acts is due to "capture" of undischarged specific work

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tensions (residual load) and how much it is due to fortuitous conditioning of general unchannelized alertness (available energy level). Most evidence points to purely fortuitous conditioning in alert young organisms as the basis for developing habit-drives. The child's sense organs are exposed to many stimuli for which he has no ready reduction mechanism. He is aroused by such stimuli, however, and tends to express his excitement through any form of motor activity that comes to hand. Thus his manipulation of blocks may not be so much a response to the block stimulus per se as it is an outlet for other undischarged energies. Children are frequently observed to go into routinized acts (such as calling "mama," pounding a board, or chasing the dog) whenever they are excited by a mass of stimuli (such as hilarious conversations of elders) for which they have no better means of response. Whenever a particular type of response becomes preferred to others (tension discharge type) we have the makings of a habit-drive. And as the child comes attached to particular types of stimulus situations in which to work off pent-up energy, we have the makings of interests and aesthetic preferences. Relatively few studies have made any attempt to measure the covert response residuals of basic need equilibration or their deflection to other situations. A consideration of clinical evidence on compulsions and interest formation may help point out an improved experimental attack.

Compulsions and Interests as Motivated Behavior. As both the world and its own response residuals are continually changing, the human organism cannot hope to maintain completely stable interactions with the external environment. It attempts to stay with some external changes and to escape from others. Because of individual differences in past associations between external stimuli and internal dis-

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turbances, each man has his own set of living standards, interests, and behavior compulsions which direct the selection of present external conditions which he attempts to enhance and maintain. Conversely, present situations and stimuli which are threatening to his habit constants are the ones he will try to minimize and escape. On the basis of clinical evidence, it has been stated that "man values positively ⁶ [favors and chooses] that which arouses disturbances for which he has specific reduction mechanisms ready. He values negatively [holds in disfavor, rejects] that which arouses disturbances for which no reduction mechanisms are ready for use." A corollary observation is that accessory equilibratory mechanisms (supplementation) used in one situation (either favored or unfavored) may serve indirectly at another time as an actual disequilibrator.

It has sometimes been argued that people seek out situations for their agreeable features alone. But a deeper analysis of underlying energetics seems to indicate that the pleasant euphoria which comes from attending a football game or a dance is mainly the indirect result of tension reduction for unexpressed (hence, unpleasant) excitement of other origin. The fact that most people think of their play, hobbies, and sport as escape from the work-a-day world indicates they are using these means to attain homeostatic equilibration and relaxation, not to further excite themselves. Daily and hourly, the harassed business man or mother of small children is displaced by situations for which he or she has no ready reduction mechanism. Some attempted partial adjustment is made of course; but pressures pile up (residual load) until the end of the day or the week finds the individual highly aroused and uncomfortable. So he begins to seek for some extraneous situation

⁶ Cf. Raup, *Sci.*, 87, 124, 1938.

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which will make him laugh, shout, wiggle, and move about, discharging thereby some or all of his pent-up energy. As he attains euphoria and relaxation from a particular line of activity, he becomes habituated to preference for that channel of discharge. Such habitual interests can be developed into drives and compulsions, especially when there is some basic disturbance or continuing insecurity to reinforce them.

Let us consider the motivational aspects of those compulsions which lie behind the tendency to keep one's clothes clean and one's home artistically arranged. The appearance of a person or his living quarters does not endanger internal constancies, as would absence of clothing and shelter, yet most of these accessory response tendencies help indirectly in homeostatic adjustment. Behavior which helps keep up appearances certainly contributes something to the margin of safety against losing one's job and hence one's food supply. Furthermore, it would appear that the more intrinsically insecure a person is about his job or position in the world, the more compulsively does he behave in reference to accessory mechanisms. The boss can ignore social norms of appearance and manner, whereas his bookkeeper is afraid to do so.

It is readily seen that compulsive acts in line with social sanction have at least a remote homeostatic function. But what of habit formations that are morbid rather than beneficent in character? A boy, for example, maintains a fear of feathers when it is of no apparent use to him. Likewise a girl persists in involuntary blushing even when she knows this behavior is detrimental to her getting or holding a job.

The motivational aspects of morbid compulsive behavior present a complex problem in higher-reaction dynamics. In exteroffective behavior, stimuli which displace the or-

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ganism may not result in the most adequate equilibratory reaction (active motor discharge type). Because of inhibiting factors, the energies that would have been naturally directed into an externalized motor response are turned inward to cause an ineffective equilibratory reaction (somatic discharge type). Because of the nonspecific character of such smooth muscle and glandular activity, the central nervous disturbance is continued (principle of backlash action). Finally, if the internal somatic tensions become self-maintaining and intense enough, exteroffective behavior is directed primarily to reducing the internal symptom rather than the original initiating cause. Psychosomatic literature is full of instances where patients want their headaches or ulcers removed but are unwilling to accept a redirection of the associated energies into more specifically adaptive channels of discharge (127, 134). Instead, many reduce their somatically reinforced tensions through compulsive discharge upon some minor stimulus displacement that happens to be simultaneously operative.

In this way are phobias learned. It is common knowledge that when a person is badly frightened without knowing why, he may later react emotionally to some purely incidental part of the original situation, such as the color seen, the fur touched, or the odor smelled. In homeostatic terms, this would probably be explained by the automatic arousal of a re-excitatory internalized reaction (somatic discharge type) followed by a compulsion to remove the minor external irritant in order that the associated internal disturbance will subside.

Thus will people straighten tilted pictures, go out of their way to avoid harmless dogs, or try to break up any bottle they find that once held liquor. Since all of these stimuli to which the individual reacts are themselves harm-

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less to essential body constancies, the equilibratory behavior directed toward them is called a morbid compulsion. Such behavior does the organism no remote or ultimate good, yet it is an attempt at equilibrating an accident of conditioning. To say it another way, the person, in appearing to react to an external source of danger, is actually homeostating only his own fear of fear.

Defense reactions and morbid compulsions carried to their logical extreme can turn homeostatic adjustment against the best interests of the reactor. A badly frightened boy who happens to associate his somatically maintained disturbance with the presence of a harmless bird turns into a man running from the sight of all birds and writing futile requests to the President to have all these alleged harbingers of ill shot at sunrise. In so doing he is left little energy or freedom of action to maintain any other far more essential environmental constancies, such as a healthy bank account and a circle of friends who can testify to his sanity. From the standpoint of limited homeostasis, morbid compulsions may remove or prevent arousal by certain displacing stimuli, but they do so at the expense of organismic flexibility for equilibrating other disturbances. Not only are they metabolically costly for what little security they provide the organism, but also they may become so generalized as to command most of the energies formerly utilized in other exteroceptive acts. When an individual's energies become so highly patterned along one channel that he adopts the postures of the persecuted, the exalted, or the melancholic and all overt behavior is distorted to a morbid end, we have the so-called "neurotic personality."

The point to be emphasized regarding compulsive behavior is that its desirability or undesirability is a matter wholly apart from the mechanism by which it develops.

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Both morbid and beneficent compulsions and interests are maintained by homeostatic regulatory action. Furthermore the adjustment sequence is the same for both "good" and "bad" habits. Since survival of a compulsion is not due to its beneficent functions alone, it is possible for such a type of homeostatic action to be carried so far that it is the destroyer rather than the maintainer of organismic integrity.

Reaction to Frustration. Much of our talk about the organism's freedom to develop any and all varieties of motivated behavior represents idealized rather than actualized conditions. In point of fact, very few high-order homeostatic sequences run an uninterrupted, unchallenged course toward equilibration. Thwart and frustration are introduced by physical restriction of the environment, by individually acquired inhibitions, and by social taboos. To such blocking of an equilibratory act-in-progress, the organism will respond in one of two general ways: (a) adiently, seeking to continue the original reaction and overcome the distraction, interruption, or inhibiting process by additional (compensatory) energy mobilization or (b) abiently, seeking to change the fundamental character of the blocked reaction and circumvent the obstruction by withdrawal to an easier and less metabolically costly equilibratory response (type of tension discharge). There are various degrees of adient and abient solutions of thwarted homeostatic acts. Both vary from the specific (high F.B. ratio) adaptive act of cerebral dominance to the relatively nonspecific (low F.B. ratio) act of automatic-thalamic dominance.

This last-mentioned type of behavior represents a return to lower and more primitive adjustment levels to which the terms aggression and regression are frequently applied.

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It is in this area that dynamic psychologists like Freud and Lewin have made their major theoretical and experimental contributions. We should be inclined to agree with Lewin ⁷ as against Freud that regression (which broadly defined also includes aggression) is not retrogressive in the sense of a return to reactions formerly operative in infancy. But since our interest is not in the outward form which reaction to frustration takes, we shall confine our discussion to the relationship between any type of overt action and recordable covert changes in energy mobilization and discharge. The great bulk of our own experimental work has sought to run such physiological checks in connection with frustration tests originally devised by dynamic psychologists.

The first significant outcome of measuring such covert reactions as muscle tension, blood pressure, and action potentials in connection with experimentally induced frustration was the finding that blocks imposed to acts-in-progress are regularly accompanied by increased general arousal, compensatory energy mobilization (44). Whether this increment will reinforce a specifically adaptive (focal part) reaction or lead into nonspecific behavior depends on opportunities afforded for the operation of principles of effective homeostatic discharge (diversification, specificity, moderation, supplementation, reactivation, and moderation). Amount of compensatory energy arousal is itself not a condition of the shift from specific to nonspecific overt behavior. Although it is harder to maintain high energy arousal than low energy arousal in specific channels of discharge, many individuals can do it. This interaction of high compensatory arousal with highly channelized discharge tends to lead to the specific (adient) carrying-through of the original act whereas low arousal with high discharge

⁷ Cf. K. Lewin, *Dynamic Theory of Personality*, McGraw-Hill, 1935.

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control tends to produce the specific (abient) substitute act. Conversely, low control with high arousal leads to nonspecific (adient) aggressive behavior whereas low control with low arousal leads to nonspecific (abient) regressive behavior. Experiments on reaction to stress questioning show that as an individual fails to maintain self-control (76), his behavior reverts to a less adaptive level, either in the direction of submission or aggression. In the few cases studied with the aid of covert indices of arousal and discharge there was evidence of a linkage to homeostatic recovery. That is, those showing submissive behavior tended to have low R.Q.'s due to undischarged tensions (residual load), whereas those showing aggressive behavior tended to a higher discharge rate during the stress testing, followed by quick build-up of re-excitatory potential due to overacting.

Two other lines of research have been advanced in connection with reaction to frustration. One measures the differences in compensatory energy mobilization under different conditions of frustration; the other measures the discharge (R.Q.) value of different overt reactions to frustration (types of tension discharge). The second type of study has indicated the superiority of nonspecific restless active-motor reactions (supplementation) over ideomotor and verbomotor reactions in helping homeostate frustration effects (77). The first type of study has a much longer history and is better understood.

The classic experiment in the field of frustration energetics dates back to 1914 and is titled "overcoming distractions and other resistances"; this study (107) showed that individuals who meet a distraction to work-in-progress with sufficiently increased effort (high A.I.) may actually over-

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compensate and attain better overt performance scores than when working under no distraction.

A later study recorded changes in quadriceps muscle tension during completed and interrupted mental work (44). The tasks, although simple in nature, were frequently accompanied by initial tension (A.I.) increments which tended to decline as the work progressed toward completion. Interruptions and blocking of these acts-in-progress by such frustrations as shutting off illumination, borrowing the subject's pencil, etc., were met in most cases by compensatory tension increments. Those subjects who increased tension most tended to resume work at the first opportunity. Thus the resumption of interrupted tasks, previously discussed in terms of "psychic tension," could be explained in physiological terms. In the competition of antagonistic patterns of excitation for control of the total behavior flux, the blocked homeostatic act-in-progress has the advantage of inertia and prior entry on its side. Being a "dominant" it obtains physiological reinforcement from the increase in muscular tension and so rises above the antagonistic excitations (created by distraction and frustration) to complete the equilibratory discharge.

The next attack on the energetics of frustration behavior utilized the voluntary inhibition of a basic urge. While in normal life the human organism is often required to defer micturition, defecation, and consummatory acts related to other bodily needs, precise experimentation has been largely impossible because of difficulties in quantifying either the strength of the stimulating condition or the organism's response thereto. It was found (53), however, that excitation aroused by bladder tension was subject to systematic control, and that the voluntary inhibition of the

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related consummatory act of micturition was reflected by quantitative changes in both general and total postural adjustment. During "holding" of micturition there appeared many stepwise increments in palmar skin conductance and in electromyographic activity of the perineal musculature. These paralleled increments in vesicle pressure and adjustment thereto. It is not known whether these changes in reactivity represented increased general irritability, or were neuromuscular reinforcements acting to offset the micturitional impulses. Both factors were probably involved in the experiment. Correlations between general arousal indices and vesicle pressure in a resting condition suggest that restless movement may serve as substitute discharge for an inhibited urge.⁸

The compensatory energetics involved in homeostating to blocks imposed against normal work demands and normal basic urge equilibrium are applicable to other types of crisis. Heightened energy mobilization has been re-

⁸ The study clearly indicates that voluntary inhibition of frustration of a basic urge involves a readjustment of the energy pattern of the total organism. Some of the energy increment is expressed through increased general activity, and some through activity of the perineal and abdominal musculature in particular. As a result of such specific activity vesicle pressure drops and the "holding" postures relax slightly until pressure is again built up. Obviously, there is a limit to the postural compensations for increasing bladder content. The potential extent to which the bladder can relax has the least function significance (cf *Brain*, 56, 149, 1933). Most important is the degree of inhibitory control which the higher nervous centers can supply over the expulsive mechanisms (which are spontaneously homeostatic-regulatory). The change in general reactivity (palmar conductance level) was found to be greatest immediately preceding micturition. If voluntary control of micturition depends upon a certain excitation threshold, heightened compensatory adjustments might indicate when the optimal point had been reached. It is regretted that this work did not push subjects until there would have been an involuntary discharge of vesicle contents. Such work would check the hypothesis more completely.

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corded at points of indecision in answering an attitude test (12), difficult points in problem solving (13, 14), and in anxiety states associated with taking examinations (83, 149). On the other hand, successful solutions of arithmetic problems (31) have been reported to involve no more neuromuscular activity than do failure solutions. This apparent contradiction, however, may have been due to uncontrolled difference in the basic energy level from which the changes were recorded, or because a "failure" was not a "frustration" to the subject. We must remember that when a subject chooses to fail at solving a problem, this itself is a homeostatic reaction. The properly constructed experiment on success and failure reactions should make an attempt to measure remainder effects (residual load). These, presumptively, are greater in the true failure reaction than in the successful solution, since we know from other studies (44) that incompleting work and blocked acts-in-progress are remembered longer than completed, unfrustrated acts.

Frustration for Enhancement of Homeostatic Effects. It is erroneous to assume that human adults will regard all frustration as undesirable. Some actually choose the more frustrating of two available situations, provided they are confident of an ability to surmount the higher barrier. Thus will a young man prefer the girl that is hard to get and the crack salesman the prospect that is hard to sell. The reason behind such choices, apparently, is that greater pleasure is derived from reducing tensions artificially raised by the additional frustration.

We must remember that the physical environment is only one source of thwart and deprivation of internal need. Besides relative absence of food, shelter, or mate, account must be taken of social taboos that condition the environ-

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mental constants that man attempts to develop and maintain. The particular society in which the individual lives helps determine what internal needs will be frustrated and what the accepted pattern of externalized adjustment will be. Some primitive societies add no social frustration of tissue needs for enhancement of homeostatic effect. If a physical thwart exists, their institutions are sufficiently loose to permit many forms of readjustment. Other societies take certain internal needs and either systematically frustrate or systematically emphasize their unbridled display. Eating in public is taboo among certain tribes, and this induced pressure undoubtedly gives private gratification much greater enhancement. Our own society taboos early sexual activity and always screens intercourse from public view. In both cases a specific physiological urge is reinforced by general energizing conditions brought on by a developed deprivation. This is probably the basic reason why the strip-tease attitude toward sex will be maintained as an environmental constant in our society. We grow up with an unnaturally reinforced sex urge, and by maintaining taboos of chastity, modesty, and privacy the occasionally obtained orgasm is made more physiologically equilibrating than it would normally be.

Further evidence that the cultural set-up can be actually stimulating to bodily needs is found in the enhancement given to the hunger drive in elaborate eating cults. Similarly, the limited homeostatic equilibration that might naturally be derived from bathing and massage of the skin was raised to an unnatural degree in the Roman bath. When the majority of a population accept the unnatural enhancement of a basic drive by developed frustration and elaborate ritual, the taboos that represent such exploitation are maintained as environmental constants by mutual consent. Fail-

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ure of individual homeostasis to dovetail precisely with group-sponsored methods of equilibrating common needs not only marks the person as "queer" but is often the genesis of unbalancing, neurotic behavior.

Conflict in Motivated Behavior. The learned inhibitions and social taboos that block and frustrate the natural discharge reactions to food and sex needs might be considered as producing internal conflict. This term, however, most properly refers to competition of antagonistic excitation patterns, each of which can develop a positive behavior outcome; that is, the organism either goes to the right or to the left, not just to the right (act-in-progress) or not to the right (inhibitory block).

Until this point, we have made scant mention of the fact that many stimuli which disturb organismic equilibrium can be reacted to by mutually exclusive mechanisms. For instance, man can run from an enemy or stand and put up a fight. In higher-order homeostasis especially the more elaborate the focal part-reaction required to equilibrate a disturbance specifically, the more likely its interference by other part-reaction patterns. Man painfully acquires a special method of "acting the gentleman," yet many social contacts tend to excite antagonistic lower-order homeostatic behaviors.

Study of the quantitative management of reflex coordination shows that conflict of excitation patterns is basic to the organism's make-up. Two kinds of interaction may exist between simultaneously activated reflex patterns. When these patterns are *allied*, one will reinforce and facilitate the other, as between ipsilateral arm and leg flexion; when these patterns are *antagonistic*, one will tend to prevent and inhibit the other, as between contralateral right and left leg flexion. With allied reflex patterns, the stronger

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will be observed to dominate in overt behavior and to derive reinforcement from the weaker pattern. With incompatible reactions, while the stronger may almost completely dominate in overt behavior, the amount of energy required to inhibit the weaker antagonistic reaction will be subtracted from that otherwise available to support its own discharge. Or, in case the incompatible reaction tendencies are of equivalent intensity, there is presented the true conflict situation, with complete blocking of specific equilibratory discharge. Here, even at reflex levels, there is overflow of the aroused excitation into discharge channels not held in check by ambivalent inhibitory processes (supplementation). Response is deflected from an exteroactively directed skeletal discharge to an interoactively maintained tension. Thus is the turmoil of ambivalent excitation built up and intensified in control centers until the entire system is loaded beyond its inherent capacity (psychiatric plimsoll mark) and nervous breakdown occurs.

Conflict in higher-order behavior is one of the most baffling problems in the whole field of motivation. The dynamics of the process are most usually dealt with in psychogenic terms, utilizing such concepts as "ambivalence" and "psychic tension." A physiological interpretation of behavior referred to such concepts is achieved by applying what we have learned concerning the quantitative management of reflex co-ordination. The total organism behaves as a unit in resolving antagonistic (ambivalent) reaction tendencies. Regardless of the level at which the competition and conflict occurs (excitatory vs. inhibitory effects in the central nervous process, sympathetic vs. parasympathetic nervous process in the autonomic nervous system, elevating vs. depressing chemical agents in the blood stream), the outcome is an algebraic summation.

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When the reaction tendencies are mutually exclusive (total ambivalence), the aroused energies overflow into any unrelated motor channels that are open, and as these discharge, their re-excitatory (principle of nonspecific backlash) effects serve to maintain the central conflicting excitants as factors in future behavior outcomes. Sometimes the overflow and redirection of aroused energies into autonomically controlled channels results in reinforcement of one of the centrally represented ambivalent reaction tendencies, thereby permitting a break-through to specific action. Again the autonomic arousal may be so strong that it forces past both ambivalent specific reaction tendencies and leads to nonspecific emergency types of discharge toward the irritating situation. There is nothing mystical in any of these dynamic operations, and all may be approached successfully by the objective methods of psychophysiological assay.

The effects of simultaneously excited reaction tendencies on neuromuscular homeostasis have been approached experimentally by means of the induced conflict situation. Following the pioneer work of Pavlov on dogs, several experimenters have shown the inevitable outcome of ambivalent discriminatory patterns in human subjects (56). As with dogs, the approach to the breakdown point of specifically adaptive behavior is brought on gradually by progressively narrowing the discrimination thresholds between stimuli for mutually exclusive (ambivalent) overt part-reactions (sensory conflict). Total energy mobilization rises under these conditions (7, 77, 78), until the excitation derived by backlash from autonomic response no longer reinforces the cerebrally directed specific adaptive discharge, but breaks through into nondirective, non-specific, nondiscriminate emergency discharge. An even

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more abrupt shift from specific to nonspecific adaptive behavior is shown in experiments that present stimuli to two mutually exclusive reaction arcs (motor conflict) (56, 67). A related variation is the revival (by word-association tests) of previously existing tendencies toward antagonistic reactions (verbal conflict) (77). In all these methods, there is evidence of disturbance and disorientation, the effects of which spread beyond the immediate stimulating situation. Such work is said to produce "a mild form of experimental neurosis" and to be an essential technique for further investigations of the reaction dynamics in conflict.

Studies of energy mobilization and discharge during the revival of persistent emotional conflicts have been made. Here the displacing stimulus (a word) induces a conflict of reaction tendencies, one toward immediate and impulsive discharge of a specific verbalization which reveals the personal value attached to the stimulus word, the other toward restraint of the highly personalized discharge and the substitution of a more neutral, socially acceptable, and less revealing response. One investigation (26), utilizing concurrent records of skin conductance and blood pressure change, showed that these measures of nonspecifically directed action are raised during the blocking of reactions in verbal conflict. Another study (108), which recorded involuntary changes in manual pressure during verbal response to conflict stimulation, indicated that variability and extent of nonspecific discharge are related to the amount of blocking of more appropriate discharge pathways; that is, the more the verbal discharge is blocked and inhibited, the more does the excitation spread to other motor systems. Mention should also be made of a study on typists (2) in which a specific general tension differential (F.B. ratio) was related to breakdown. The use of similar

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procedures served to distinguish the reactions of adjusted and maladjusted children to frustration (69).

Investigation of the energetics of newly developed conflicts has been made possible in several tests that train the subject to utilize limited mechanisms for differential reaction to specific stimulus displacements and then make it progressively more difficult to utilize these mechanisms. The general principle is to give success followed by failure. Such a situation was developed by forcing sensory discriminations with electric shock punishment for mistakes (67). The few easy discriminations provided control scores for performance and energy mobilization; difficulty was then increased until three consecutive failures were made, after which the subject was immediately returned to the easy discriminations for a record of his "recovery." Aside from the question of individual differences, several significant relations were found. For one thing, the overt performance score was not nearly as accurate a measure of the difficulty of homeostatic adjustment as was the record of energy mobilization (palmar skin conductance). Not only were compensatory increments noted, but also a widespread diffusion of aroused excitation to motor activities only remotely connected with the specific finger reaction discharge. Homeostatic recovery, as measured by palmar skin conductance, was found to be related to recovery of overt performance, as measured by return to the scores made on the easy control tests. Frustration studies (69) on school boys indicated that differences in initially high or low skin conductance are unrelated to subsequent patterns of behavior. However, boys who showed the greatest *variability* in energy mobilization during the test tended to recover most slowly from the experimentally induced frustrations. This type of approach has been recommended for

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measuring individual differences in reaction to stress (63) and for study of covert activities underlying various types of resolution of conflict.

Types of Conflict Resolution. Conflicting reaction tendencies cause profound homeostatic displacement in situations where inability to master a problem is paired against an inability to escape from it. The two simplest "emergency" resolutions of conflict—fight or flight—are not of much use here. Instead of *avoidance by withdrawal* or *destruction of barriers by aggressive attack*, the resolution of the conflict tends to take the form of either a *defense by compromise formation* or a *catastrophic breakdown*.

While all four types of resolution of conflict can be demonstrated clinically in man and experimentally in animals, *catastrophic breakdown*⁹ has commanded the major attention. The psychotic disorders fall into this class, and so do the more drastic type of experimentally developed neuroses of animals. Great bodily excitement precedes the catastrophic state. Though in the largest context one of the ambivalent reaction tendencies may not be vital at all, but rather a false means to an end, it will be as strongly

⁹ This term is borrowed from K. Goldstein's excellent discussion of the "inadequate, disorderly, inconstant, inconsistent behaviors embedded in physical and mental shock." He goes on to say (*The Organism*, American Book, 1939, pp 37-41) that "after such a breakdown, reactivity is likely to be impaired for a longer or shorter time. The patient avoids all situations that might occasion further catastrophic reactions and tries to maintain the situation with which he can cope. . . . The significance of these substitute performances rests not so much in their contents, as in the fact that they lie within the capacities of the patient. . . . At a certain stage of disintegration, they are the last resources, the only means by which existence can be maintained." The behavior observed in some of Maier's rats (*Studies of Abnormal Behavior in the Rat*, Harper, 1939) is analogous to the catastrophic breakdown reaction of Goldstein's human patients. But a continuing neurotic defense compromise can also be built up in animals to prevent catastrophic breakdown.

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reinforced by autonomic processes as is the more basic need. Resistance to a single line of overt discharge is enhanced by vacillations and attempted protections from breakdown, often referred to as "basic anxiety." As a result of all this stimulation, tissue activities are aroused which put back into the system more excitation than they have released. Such circular build-ups quickly deplete the organism's reserves (available energy level), and the overt behavior which does emerge is disorganized, primitive, and nonspecific in character. Any part of this disorganized display of activity may be fixated as an adjustment to the conflict situation. The organismic system "accepts" the reaction pattern of the paranoid, the hebephrenic, or the catatonic and rebuilds its bodily economy around the new behavior dominant. Homeostatic adjustment is finally achieved, but at the expense of losing contact with many important aspects of the individual's environmental field and previous habits of conduct.

Resolution of conflict by *compromise formation* is not too difficult when antagonistic reaction patterns (tentatively excited by some internal need displacement and by a learned inhibitory tendency looking toward long-time security) are not too strongly aroused. The learned inhibitory tendencies which are aroused by external cues are at first centered only in preventing the unlearned or low-order homeostatic adjustment from occurring. By way of autonomic reinforcement, the inhibition is at first built up against more responses than are required; but in the normal course of events, some outlets are "released" and become partial and substitute discharges of the ambivalent excitation. The tighter the control over the skeletal muscles (the discharge mechanisms normally most subject to inhibitory conditioning), the greater the tendency for the aroused ex-

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citation to discharge through internal tissues (somatic type of tension discharge). Here the complete behavior description will usually reveal, behind the calm front of overt behavior, some organ tension (tachycardia, colitis, etc.) associated with blocked excitation and serving as a feeble "release valve" in homeostatic discharge. In fact, all substitute compromise reactions can be regarded as attempts at equilibration when a more natural discharge outlet is blocked.

In the homeostatic resolution of conflicting displacements, too much attention cannot be given to the automatically energized emotional reinforcements. When these become too great, the central nervous system tends to be governed almost entirely by internal stimulation and thus is out of contact with the external environment. If the behavior which develops is at all successful in removing the conflicting stimulation, as when an adult "gives in" to a tantrum-throwing child, the behavior will tend to become stereotyped; otherwise the habit is quickly unlearned.

There is some general reinforcement to be derived through conflict, provided it is short lived. Young organisms appear often to seek this excitement by playing with fire, while the old avoid it. This is probably because in youth there is more prompt recovery from exhaustion and less chance of establishing the behavior of fatigue as a response to the eliciting situation. Advancing age does not yield as much neuromuscular reinforcement to help resolve a conflict, and also there is a greater tendency for the exteroceptive system to break down when working at resolution of conflicts under forced draft.

Inadequate reinforcement of conflicting reaction tendencies may be evident only when the person is subjected to great or repeated drains upon his energies. Such a person

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is excited by ambivalent stimuli, but the disturbance is not sufficient to force a full adjustment. Such a person "gets mad, but not mad enough." He discharges his aroused excitation over inappropriate mechanisms because these are the ones that can be activated by the energies aroused. The basis for such "choices" of discharge may be either the inadequacy of the system to more metabolically costly action, or the use (as in hysteria)¹⁰ of a physically weak system which cannot resist serving as the discharge mechanism for another and unrelated type of excitation.

When a weak energy system faces a decision between conflicting behaviors that is beyond its capacity to resolve, fatigue and exhaustion are natural consequences. Energy stores are drained by continued attempts at resolution. Because of this drain upon bodily energy, little is available to carry on normal regulatory processes of living and so the entire system may become debilitated.

In the reversion to more primitive levels of homeostatic adjustment, the person may even become a simple vegetative organism. Institutional care must be afforded to such cases, as well as to any catastrophic resolution of conflict. For when the pattern of homeostatic response is so fixed that the individual is not specifically adaptive to variations in the environmental field, he has to be protected from harm by forces outside his own system.

Current emphasis in psychopathology, toward which all discussions of motivated behavior ultimately gravitate, is upon the physiological depth and duration of the malad-

¹⁰ Janet (*The Major Symptoms of Hysteria*, Macmillan, 1929) recognized that the starting point for most neuroses "is in exhaustion of the higher functions of the encéphalon—our nervous strength presents oscillations—and the lowering of nervous tension (as by great expenditure of nervous strength in emotion) brings about a general lowering of the highest functions."

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justment. The longer a person is allowed to pursue a faulty resolution of conflicting reaction tendencies the more deeply ingrained the habit becomes. When he gets firmly set on the postural course of the persecuted or exalted, psychotic, even deep physiological shock therapy has but limited value. The flexibility and adaptability of learning are all but lost as one act of homeostatic adjustment dominates the entire energy system. What was intended to be man's fortress thus becomes man's prison.

CHAPTER VI

Learning

Modifiability in Homeostatic Maintenance Operations. Throughout the preceding chapters there have been repeated references to the learning process, to modification of behavior. We saw how, in homeostating internal needs, exteroffective action is conditioned to external change. Inherited emotional reactions were found attached to an endless variety of stimuli. Drives, interests, and motives were also shown to bear the imprint of situations through which the individual has passed; his successes and failures with surrounding physical and social environments modified subsequent reactions and oriented his strivings. In all reaction, we saw an attempt to develop optimal conditions of homeostatic adjustment.

There is an apparent inconsistency in regarding the environment (external or internal) as a pattern of constant states that the organism strives to maintain while emphasizing at the same time the tendency to improve on these maintenance operations. Modifiability becomes, however, a natural attribute of homeostatic doctrine when *reaction is subjected to longitudinal rather than cross-section analysis*. Until now we have considered mainly the cross-section attempts to restore a pre-existing equilibrium. But even the simplest exteroffective reaction to displacement does more than return the organism to the *status-quo-ante*. Every overt reaction reports back to the central control

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apparatus via proprioceptive pathways (principle of backlash action) and leaves the organism somewhat different from its condition before reaction was made. Regardless of whether the backlash effect is maximal or minimal, specific or generalized, it tends to modify the internal state and "set" the organism for *new* reaction on repetition of the *old* displacement. Such modifiability is most limited in adjustment to basic internal needs and greatest in the maintenance of developed externalized needs. Longitudinal study of reaction series shows that each individual reaction, while equilibrating its own stimulus displacement, tends to set the organism for greater efficiency in subsequent reaction to similar displacement. The reasons behind this drive to improvement constitute the fundamental problem of the psychology of learning.

The Problem Stated. Consistent with our general point of view we shall regard a learned response not as a new and unique process, but as a natural extension of exteroceptive homeostasis. At every moment, external and internal changes disturb equilibrium; the organism possesses various overt response mechanisms potentially capable of restoring internal balance and uses the best of these then available. But since any reaction made is itself somewhat disequilibrating, repetition of the disturbance falls on a different organic background and calls forth a modified reaction pattern. When we compare the first and the last members of a stimulus-response series we often note an improvement in adjustment. Then we say the organism has learned.

Broadly speaking, learning can be defined as a temporal process of adjustment in which a series of responses to similar stimulus displacements modify behavior in the direction of greater efficiency, i.e., better output at less energy expenditure. The final part of our definition is very essential,

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for mere modification of behavior is not learning.¹ The later terms of a response series will always be modified because of earlier terms that have occurred; but unless these later responses are more to an organism's advantage than the earlier ones, no learning is said to occur. The total *learning series* must converge to a homeostatic optimum and lead to conservation of neuromuscular effort. A burnt child that uses its previous responses only to acquire a technique for plunging its hands farther into the flames is not a learner, but a candidate for an institution for the feeble-minded.

At first glance one may be struck by what appears to be the narrow limits set by the homeostatic definition of learning. The main objection which will probably be raised is the apparent exclusion of "bad" habits from this definition. In dealing with this objection, we may rule out at once all habits which are judged "bad" from the point of social approval. From a homeostatic standpoint, such habits as masturbation, nose picking, swearing, lying, and cheating are actually included in our definition of learned reactions by reason of the fact that they are physiologically equilibrating; and the person tends to become more efficient in these practices the longer he keeps at them.

There is, however, another type of "bad habit," such as may be pointed out to a novice by the expert in a given skill, and this requires some elaboration. The "bad" habit of typing by the "hunt and peck" system may be perfected to a maximal level of efficiency, but, if the individual wishes to pass beyond this plateau and approach the performance

¹ Modifications referred to learning are distinguishable from those due to the slow changes of growth or to fatigue, where the relative unresponsiveness of one reaction pattern renders a concealed reaction more easily elicitable. Both these latter types of modifiability are diffuse and massive rather than specifically directed to the displacing situation.

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of the expert, he must change to the "good" touch method. Whether such a change from "bad" to "good" habits will occur depends on how disequilibrated the individual becomes and the subsequent stimulus changes. The functions of the expert are to disequilibrate the novice and to instruct him in the use of better work methods. Of these functions, disequilibration is of primary importance, and it is done in many ways—actively by punitive grades, ridicule, "pep talks," and other inspirational methods; passively by unintentional neglect, the odious comparison of performance, and the consequent envy aroused. The novice who accepts the expert's challenge is so disequilibrated that his old work methods which were readjustive to a lower order of displacement (personal standard or aspiration level) are rendered inadequate. His system is consequently "open" to the development of new and more efficient work methods or homeostatic processes.²

Any description of learning as a homeostatic process must recognize the fact that some individuals appear to many others to be disequilibrating themselves. Such disequilibrations actually result from stimuli or stimulus relations which are beneath the discrimination threshold of

² The implications of this account of learning may seem at first glance unnatural and cruel. For one thing, it might condone the procedure of throwing novices in over their heads and then standing on the bank and exhorting all who can to swim for their lives. K. Lewin (*41st Yearbook, National Society for the Study of Education*, page 232) has described the learning of Nazi youth, who are systematically forced into a situation to which they have to adapt themselves in order to survive. All learning is to some extent forced, and a rather narrow line separates the unfoldment procedures of democratic education and the force methods of authoritarian states. Nurturing a so-called "natural unfoldment" simply means that care is taken to present new situations (to which the child must learn to adjust) in such a way that the displacements coincide or appear to coincide with latent and potential needs known to exist at that time.

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the less responsive individual. The latter is always at a loss to understand what excites the other fellow; even if the more complex stimulus relations are pointed out to him, he either does not sense the possibilities of a higher order homeostatic adjustment, or equilibrates by "letting George do it."

Another aspect of homeostatic learning is the process of inhibiting a naturally re-equilibratory act in order to avoid by this action the establishment of an even greater disequilibrium. This is shown by the relative absence of food stealing in a decade of economic depression. Although an actual lack of nourishment disequilibrated many individuals, fear of jail constituted an even greater threat to personal integrity. We shall see that such developed inhibitions are involved in many neuroses.

Types of Homeostatic Learning Series. Most of the response series that fit our definition of learning fall into three divisions. First are the instances of *negative adaptation, or inhibitory conditioning*, where succeeding stimulation brings about a diminution of an undesirable but well-established response. Second are the instances of *positive adaptation, or facilitory conditioning*, where succeeding stimulation is accompanied by the gradual accretion of a more adequate new response. Third are the *apparently sudden and insightful new response developments*, wherein many of the steps in the learning process are not as obvious as in the first two instances.

The homeostatic process is basically similar in all these cases, a re-equilibration of displacement with progressive modification of a unitary response series in the direction of minimal energy expenditure. Always in the acquisition of a "new" response, there is linkage to "past" response. Thus, the decay of an old response in *negative adaptation*

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is the indirect result of a learning series which has as its positive aspect the development of a new and more economical way of responding to displacement. With the gradual accretion in performance which characterizes *positive adaptation*, it is relatively easy to see that each succeeding part of the total response sequence is a homeostatic improvement, even though little attention is actually given to the responses which are being replaced.

Insightful learning presents less obvious relations between succeeding parts of the response series; but this is largely an artifact of the observational situation. Insight appears only when the stimulus displacement can be successfully disequilibrated in an all-or-none situation and where the essential prior parts of the response series are usually below the threshold of overt reaction. Yet it is probably because of movement-produced residue of previous incipient trial-and-error behavior (principle of backlash action) and of reactions made in a more remote past that the highly insightful adjustment emerges with such apparent suddenness. An analogy here would be the heating of water, in which the antecedents of "boiling" cannot be seen by the eye alone. An actual measure of energy expenditure in the insightful learning series would undoubtedly show that the successful solution was preceded by some period of great inefficiency—no output in terms of performance criteria with considerable input of energy.

To surface observation, serial responses often seem irrelevant and discontinuous from the conditions which develop the final closure or insightful solution; hence *organization* is sometimes made paramount in learning. Our homeostatic account fully comprehends this principle. Each repetitive (cross section) part of a learning series is an organized (focal-background) totality, and so is the entire

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(long section) series. Furthermore, each attempted adjustive act is as equilibratory and integrative with reference to the conditions then operating as is the final response. Each response made is "closed," and the organization progresses toward the goal of maximum homeostatic efficiency by the method of successive approximations. The progression is obvious in the first two types of learning series, concealed in the third or insightful series. The final closure in all learning series occurs when the organism is most completely equilibrated. And while not always apparent, only from the standpoint of that end result or final "closed arc" is the last part of a response series better organized than the first.

The acquisition of a new response is not a progression from utter chaos to order, as some would have us think. It would likewise be in error to consider trial solutions of equivalent stimulus displacements as separable from the total series. Whenever this is done, we find it necessary to invoke a special organizing faculty to account for modification. The concept of organization adheres in our description of a learning series, for the individual S-R adjustments are part of a larger, more inclusive homeostatic sequence. Organization is the product, not the cause of learning and no new explanatory principle is needed because of the less obvious serial character of the insightful type. All three types of learning series are merely an extension of the basic principle of homeostatic adjustment.

The Conditions of Learning. Psychologists distinguish three classes of conditions affecting the learning process. The first group covers those conditions present at the time a learned act is reproduced. The second group covers those conditions (of forgetting) that operate during the interval between learning and reproduction. The third and most

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important group covers those conditions that account for the original fixation. It is with this last group that we shall be chiefly concerned.

The conditions that develop new adjustments are readily illustrated by Pavlov's classical conditioning experiment based on the salivary reaction of the dog. If the hungry (displaced) dog is put in a restrictive situation when food may be had, and if a previously irrelevant (bell) stimulus is paired systematically with feeding, the animal acquires a new salivary response to the bell in anticipation of the digestive requirements of feeding. This conditioned response may be elicited in the absence of the basic food (unconditioned) stimulus to salivation; but unless such reinforcement is given occasionally, the conditioned response has lost its anticipatory homeostatic value and so suffers extinction. The essential conditions of conditioning appear therefore to be the serial presentation of the conditioned stimulus along with an unconditioned stimulus which developed, directly or indirectly, the reinforcement of a natural homeostatic response. The basic statement for the entire process is that anticipatory conditioned homeostatic reactions (when aided by reinforcement from a more basic disequilibrating condition) progress toward an optimal level of efficiency, giving the negatively accelerated learning curve; conversely, when the anticipatory (conditioned) homeostatic reaction is not reinforced by the basic disequilibrating condition, it is progressively decreased until extinguished, giving the positively accelerated curve of forgetting.

The effective conditions for such learning are covered by four principles. Each will be discussed in turn, together with relevant experimental data on both output and input changes.

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The Principle of Contiguity. In any learning series, shift from one stimulus-response organization to another is thought to be dependent upon the temporal and spatial contiguity of an already existing response and of excitants for the one that will replace it. Contiguity of external excitants is clearly in evidence in classical conditioning experiments, but difficult to demonstrate in some types of learning. Experiments have been devised purporting to show that learning takes place without contiguity. This may be true at the overt level of response. But covert residua are known in certain instances (126) to have supplied a contiguity of excitation between part-reaction sequences (principle of backlash action).

The first and most obvious place to study the influence of specific backlash (movement-produced) residua on subsequent response is in connection with successive comparison judgments (130). Although the effect of first weight lifting on judgments of heavier or lighter for second weight liftings has long been known, the explanation of this contiguity effect has been shrouded in mystery. But when study was made of the covert residua of first weight lifting, it was found that outlasting action potentials in the lifting muscle accurately predict the comparison judgment (80). Likewise, specific covert residua from reacting muscles were found as effective agents in motor conditioning of the dog (57). Outlasting proprioception from completed overt response, as indicated by action potential records, runs a cyclical course of rise and decline (128). Maximal transfer and fixation effects tend to occur when the second segment of a response series supervenes upon the peak of the curve of specific response residua from the first segment.

Studies of gradients of reinforcement in conditioning clearly show that these are dependent upon the way the

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unconditioned (reinforcing) response is aroused and the place in the learning series where the interval between stimuli is systematically changed (39). This suggests that the second term of a paired response series is being superposed upon the residual response curve of previous stimulation. The most favorable interval for conditioning is slightly greater than the latency of the conditioned response, thereby permitting anticipation of the unconditioned response to connect with presentation of the conditioned stimulus. Outlasting backlash excitation maintained by postural adjustments seems the most likely basis of contiguity in so-called anomalous instances of trace, goal gradient, and backward conditioning (83).

We shall have more to say about the optimal timing for contiguous association in our discussions of conditions affecting retention. For the present it is sufficient to point out that one does not need to hypothesize "central traces" to explain association between the individual stimulus-response parts of a total learning series. By use of covert behavior indices, it is possible to trace these traces in terms of their peripheral accompaniments. Today we recognize that the only contiguities that matter in learning are contiguities of response and response residuals. Placing two stimuli in the same space and time sequence assures that responses made to each will dynamically interact. Thus the dominant response pattern may come to embrace the excitant of the nondominant response and so be raised to supraliminal (overt) strength by the previously inadequate stimulus. Or a totally new response may emerge from the learning series, being the product of all response residuals remaining from previous trials and their associated stimulus excitants.

The Principle of Exercise. Although the current tendency

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of psychologists is to subordinate the role of exercise, all agree that repetition is needed in order that more relevant conditions of learning may operate. The increment in effectiveness of overt response which comes with practice is well known. A negatively accelerated curve of acquisition has been plotted for nonsense syllables, maze running, and percentage of conditioned responses to total reinforced stimulus presentations. That growth of strength in conditioned responses is indirectly due to exercise may be inferred from their amplitude and latency, as well as their frequency.

In all this work, however, the progressive changes in energy input which accompany and support the output changes have not been surveyed. As a result, there is something of a hiatus between underlying energetics and the increase in performance scores with practice.

It is easily demonstrated that increased general energy mobilization (A.I.) tends to have a facilitative effect upon the rate of improvement in specific adaptive behavior. The pioneer experimenter (3) in this area had subjects grasp dynamometers to increase general neuromuscular tension during the learning of nonsense syllables. At about the same time, another experimenter (45) recorded the natural energizing accompaniments of such learning in terms of quadriceps muscle tension. He found that one of the first effects of a learning situation (where a need for improvement is aligned with organic disequilibrium) is an increment in general muscle tension, presumably operating to force a specific equilibratory discharge. Also, at first the specific overt reaction appears relatively unadaptive, as measured both by low output scores and the relatively small reduction of aroused tension (residual load). As similar stimulus displacements continue, a greater economy of

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effort is attained. Not only is less general tension aroused by each serial displacement but the residual amount following the specific overt equilibratory discharge is also progressively reduced (lowered R.Q.).

If the tensions of the quadriceps muscle are taken as symptomatic of covert input changes and nonsense syllable scores are taken as indicative of covert output changes, a very neat relationship can be plotted. As shown in Figure 7,

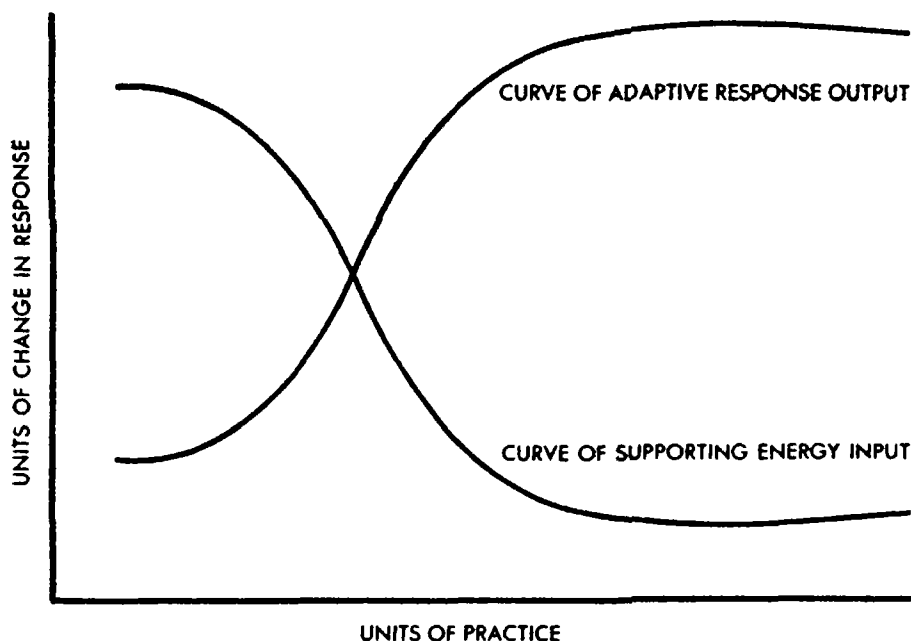


Figure 7 Effect of practice on output-input relations.

under continued practice the curves of output and input in a learning series tend to be inversely related. For the initial steps of the series a great amount of general reinforcing activity is necessary to accomplish a minimum of specifically adaptive behavior. Later a period is reached where a certain minimum of energy input (A.I.) is accomplished by a maximum of output (D.I.). From such a point on, theoretically, the two curves should be asymptotic, rep-

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resenting the highest level of homeostatic efficiency to be reached.

Experience has shown that either the input or output curve may rise with practice without causing any shift in the other aspect of adjustment. The first condition has been demonstrated in distraction experiments (28), where compensatory increments in general energy mobilization act to offset intercurrent factors otherwise detrimental to output. The second condition has been demonstrated in both distraction and learning experiments (20, 55, 120), where a shift in the pattern of reinforcing tension from nonfocal (general) to focal (specific) muscles is accompanied by increment in work output while the total level of energy mobilization remains the same. Later, we shall have more to say about the distribution of aroused energies in learning. At the present time it is sufficient to point out that under practice or exercise the patterning of response (F.B. ratio) also proceeds in the direction of greatest homeostatic efficiency.

The practice relationship between supporting general tension and overt performance is also apparently confirmed for anticipatory and residual tension in muscles focal to the learned equilibratory act. An investigation (137) of stylus maze tracing showed that pressure on the stylus increased as the more complex and difficult parts of the learning series were reached. Mean tension for easy short mazes was somewhat less than for longer and more difficult ones. The relation between tension and degree of maze difficulty turned out to be more reliable statistically than did the relation of tension to degree of logically defined complexity (31). In general, the longer the learning time, the greater was the decline in focal (specifically localized) tension with practice. In a related experiment (62), however, focal tension

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was maintained at a fairly uniform level while subjects learned a manual multiple choice problem. After the problem was mastered the amount of tension in the used arm dropped rapidly and its variability decreased. This study and another (57) showing the tension accompaniments of conditioned response formation in the dog have considerable significance for the principle of exercise. When the end term of a learning series is reached, there tends to be such close correspondence between patterns of energy mobilization and discharge that the general energy level is only slightly raised by the stimulus; that is, the stimulus is minimally displacing and the equilibratory reaction maximally adaptive.

The most telling argument against the efficacy of exercise per se is provided by *experimental extinction*, where unreinforced CRs are weakened rather than strengthened by successive stimulation. Pavlov has argued that such extinction is due to the development of internal inhibition in the conditioned response pathways of the nervous system. A far less questionable explanation, however, can be advanced in the light of the input changes recorded in learning series. It should be remembered that the quiet and highly controlled conditions of Pavlov's experiments were such as to induce muscular relaxation in the animals when no reinforcement was used. This fact has led to the suggestion that Pavlov confuses the specific (extinction) decrement with a general decrement in all responses when the background of general muscle tension is reduced.

Quite naturally, also, a newly learned homeostatic response will be eliminated by exercise if the condition it anticipates never appears. But while exercise may be used to make or to break habits, there must always be at least one repetition in order that stimulus response patterns may

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interact. Depending upon the complexity of the readjustment required to meet a given situation and the relative availability of quasi-appropriate equilibratory acts, more or fewer stimulus presentations will be required to bring the effective factors to bear optimally.

The Principle of Effect. Learning studies seldom escape the implications that the consequences of an act—that is, reward or punishment—are influential in the selection of the final adjustive response. This so-called “law of effect,” as formulated by Thorndike, has been of practical value in animal experimentation and educational method, albeit the underlying process is not clear.

Few statements about learning have excited more controversy than the principle of effect. Most objections have been based on the presumption that outcomes cannot themselves influence conditions originating them. Such a thing is difficult to conceive neurologically, and the hypothesis that pleasure releases more neural energy for reinforcing the patterns of successful movement than does pain is contrary to fact. Painful states are very displacing and cause high energy mobilization (A.I.), whereas pleasurable, successful acts normally cause relaxation. Pleasure and pain as effective conditions of learning have also been ruled out by experiment (140). Reinforcement of “right” responses by means of a painful electric shock increased rather than decreased the rate of serial learning. Emphasis and not pleasure-pain is the basis of such reinforcement in learning.

There is little doubt that the completion of a successful homeostatic adjustment leaves a stronger trace than does a less satisfactory response (15). But the theoretical objections and contradictory experimental results point to a need for reformulation of the principle of effect. Neither pleasure nor pain strengthens a reaction tendency. Rather,

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those responses which lead to *tension reduction* and the equilibration of a basic disturbance tend to be repeated and learned.

This formulation helps explain the continuance of varied behavior until a problem is solved. It has long been recognized that the successful act in a learning series is also the last act. This last act discharges most of the excitation developed by the original displacing condition (high R.Q.). On such a background of relative central quiescence the specific proprioception (backlash action) from muscles that accomplished the solution may focalize, and, following Bok's principle of the reflex circle, be sufficiently prolonged without confusion from other motor residua to register. Under these conditions of tension reduction with the successful act, less retroactive inhibition results and a greater chance obtains for fixation of a specific trace. Here we can only scratch the surface of what is one of the most crucial points in learning. Theorists like Hull and Guthrie³ prefer expectancy and contiguity-substitution principles as the explanation for fixation over even the tension-reduction formulation of the law of effect. This is probably because it often appears as if the fixated act is not tension reducing. The child's preference for a noise-making toy and the dog's eagerness to join a dog fight are cited as evidence that men and animals learn to do many things that result in tension increase. At a less superficial level of examination, however, it appears that such reactions might reduce tensions aroused by one set of conditions, while at the same time creating other tensions.

Tension reduction in learning does not necessarily mean

³ For a statement of these and other related views cf. L. Postman, "The history and present status of the law of effect," *Psychol. Bull.*, **44**, 489-563, 1948.

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that the equilibratory act is accompanied by general relaxation. Though this is frequently the case, often there is only a *redistribution* of the tension pattern relative to the field situation in which the organism is operating. The child's choice of a whistle instead of a block, the adventurer's courting of danger, and the schizophrenic's performance of a ritualistic act are all physiologically equilibrating. They operate, however, not so much by general tension reduction as by redistribution of tension about a new focus.

An act that reduces certain tensions may initiate other tensions, but its value as the terminus of a learning series is its outlet for the discharge of an initiating excitation and the stabilization of a reflex circle. As long as a persistent stimulus effect is not adequately discharged, it tends to keep the system excited; behavior is nonequilibratory not because general tension remains high, but rather because this tension is so distributed that no act is self-reinforcing, environmentally adequate, and physiologically efficient. The performances of novices should be compared with that of skilled workers in these regards.

In line with our homeostatic treatment of behavior energetics, it must be presumed that the reduction of disequilibratory strain is basic to the fixation of learned acts. Even where the performance of such an act may actually increase the general energy level, as in the case of certain compulsions, this is probably the lesser of two evils. Taken in the total frame of reference, such acts can usually be seen to reduce persistent excitatory strain.⁴

⁴ As a reciprocal of this, too great excitation may interfere with fixation. Wegner (*Psychol. Rev.*, 44, 297-312, 1937) has pointed out that many of Pavlov's internal inhibition explanations of unstable learned response need to take into account the high general energy background.

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The Principle of Set-Expectancy. In a previous chapter we have indicated that covert set adjustment often anticipates the overt aspect of response. This provides a fundamental condition of learning. In the course of repeated stimulus displacements, the covert response residuals which outlast overt discharge become the "set" which anticipates the next response in the learning series. This has been demonstrated experimentally in connection with conditioned motor reactions of the dog (57) and with a manual pursuit skill in human subjects (45). When the animal is first placed in the harness, there is aroused an attitude of apprehension or an alert "expectancy posture." This expresses itself in general tension increments and restless movements of all four limbs (A.I.). The dog does not know from what quarter to expect punishment or reward and is prepared for a wide range of possibilities. This general increase in activity in all limbs is operating when the combination of conditioning tone and unconditioned shock stimulus is first presented. Such activity continues longest in the limb actually receiving (and overtly responding to) the shock. Consequently when the conditioned stimulus is again applied, it meets a differential postural adjustment with major anticipatory activity concentrated in the limb whose movement constitutes the most appropriate homeostatic adjustment to the situation. Repetition of the stimulus combination brings about a reduction of tension in unstimulated limbs, and the "capture" of the differential set-expectancy by the conditioned stimulus. This capture presumably occurs through lowering of threshold for response to the bell alone by increased proprioceptive backlash action in the motoneurone field involved in foot withdrawal. Finally, therefore, even in the absence of the unconditioned shock stimulus that the covert set anticipates, a weak approxima-

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tion of withdrawal is made. The covert set-expectancy, at first outlasting and then anticipatory of shock displacement, differs from the adequate conditioned equilibratory discharge mainly in degree. The total learning series may be regarded as a special instance of a highly developed covert set-expectancy merging into overt action before the actual occurrence of the expected stimulus. This is what is ordinarily referred to in conditioning as a "coming forward" of reaction.

In recent years, set-expectancy factors have become increasingly important in the explanation of conditioned response series. Antecedent postural adjustments without overt responses are taken as evidence of learning, as in the conditioning of the galvanic skin response (41, 83) and covert movements of the limbs (53). In fact, the phenomena of "generalization" of conditioned response and "cross-conditioning" are best explained by set-expectancy factors.

The principle of set-expectancy is an extension of the principle of effect. Assuming that learning develops only as a reaction system undergoes tension reduction, a mounting anticipatory tension which precedes the presentation of a recurrent stimulus is seen to produce by backlash excitation an approximation of the anticipated stimulus and lead over into a conditioned response.

Another factor in set-expectancy is the limited number of substitute stimuli which a set will permit to act as excitants for a given conditioned response. It has been pointed out many times that mere contiguity of stimuli does not assure that their effects will be associated. In fact these effects can be accurately predicted only in terms of their relation to set-expectancy. The parts of a learning situation that are associated have to belong together. And this be-

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longingness is probably nothing more than common set-expectancy. For instance, only if the stimulus regularly precedes the unconditioned stimulus will it belong to that set-expectancy pattern. Organization factors in learning are aspects of set-expectancy.

Motor residua subside rapidly after completion of an overt response and then tend to rise again (125, 132), thereby forming the peripheral components of set-expectancy for most stimulation. As this set-expectancy mounts to a peak, it may discharge automatically as an overt reaction. Any new stimulus appearing prior to the expected unconditioned stimulus may serve as trigger to discharge the mounting set-expectancy through overt response. Only when the new stimulus regularly appears, however, will such overt response meet the criteria of conditioning.

Transfer of training is basically a matter of set-expectancy. The evidence for such transfer is best in cross education, where positive transfer develops between bilaterally symmetrical parts of the body. Exploratory experiments (28) make it appear that Thorndike's theory of identical elements is not as adequate as is Davis' theory of spread. The latter postulates an actual use of the apparently unpracticed part by spread of set-tensions thereto. The fact that transfer effects are mainly ones of general expectancy, attitude, and method of attack argues for a set-expectancy basis. Furthermore, in cross education, there is experimental evidence showing the covert activation of contralateral parts during training.

Conditions of Retention. Evidence accumulates that extinction of previously acquired responses is not a passive form of decay, but is due to the interference of other reaction tendencies with the strength of the trace under study

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(retroactive inhibition). This fact was shown in dramatic fashion by comparing the rapid rate of forgetting nonsense syllables during waking with the slower rate for an equivalent amount of sleep (95). If a time factor alone was responsible for the decrement in newly acquired homeostatic adjustment, the curve of forgetting for sleep and waking should approximate each other. That the rapid forgetting shown in waking scores is due to the inhibitory effects of interpolated activity has been indicated by many experiments. Not so well demonstrated, however, is the proposition that response residuals may be affected both positively and negatively by subsequent activity. There is good reason to believe that maximal retroaction (forgetting) occurs when the second activity is neither enough like the first to reinforce it or enough different to inhibit it. But, even sheer quantity of interpolated activity affects retention differentially. Between the learning and recall of nonsense syllable lists, subjects in one experiment (115) pressed on levers to sustain various weight loads. It was found that mild interpolated general tension will cause little or no retroaction, whereas heavy general tension will interfere with the fixation and retention of traces of previous focal action.

Factors that offset the inhibitory effect of interpolated activity include overlearning and the proper spacing of repetitions. It has been demonstrated that overlearning, up to a point, builds specific response residuals considerably in excess of those involved in immediate response development. Presumably the excess acts to compensate for interference effects. The favorable influence on retention of the proper spacing of repetitions is apparently due to reactivating at the moment when the residuals of the previous response are at maximal strength. Response residuals that

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follow a cyclical course have been shown in certain instances (128) to form the basis for the favorable work resumption after rest pause.

Energy Distribution in Learning. One of the most significant fields for future research in learning covers shifts in the distribution of aroused energies during acquisition, retention, and reproduction of new homeostatic adjustment. In the past, far too much attention has been given to the quantity and quality of the overt (focal) part-reaction (number of nonsense syllables learned, amount of maze mastered, quality of mirror tracing, speed in achieving a specific food goal, etc.). The consequent neglect of covert (background) part-reactions which support and sustain the overt response sequence has resulted in a number of unexplained anomalies. For instance, why does the performance of a novice at some motor skill involve much more energy expenditure than that of the expert? Also, why, after a plateau is reached, is there often subsequent improvement in focal behavior without a compensatory rise in background-energizing activities?

Both of these questions are answered by experiments which study concurrently the overt (focal) and covert (background) reactions involved in learning. In one experiment simultaneous records of tension in the right and left arm and leg muscles (45) were taken during the learning of a complicated eye-hand co-ordination test (manual pursuit of a moving object). At the beginning of the learning series, tension accompaniments were widely distributed. But as learning progressed, the increased activity tended to be confined more and more to the focal part that moved the reaction level. This suggestion that the reduction in general activity level (A.I.) occurring under habituation of a focal act is due to a higher degree of specificity

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(F.B. ratio) in the pattern of supporting tension. It was further shown that a shift in tension pattern or energy distribution frequently occurs during the plateau period, and while not accompanied by a reduction in general energy level, the more economical distribution of the same energy quanta (concentration in the overtly active part) brings improvement in focal performance. A similar finding (55) applies in learning to overcome the effects of a distraction, such as working at mathematical problems under noise. At first there is an increase in the tension of all four limb muscles studied. Later the tension concentrates largely in the muscles performing the focal (overt) response.

It is useful to consider the differential tension patterns that support overt focal performance from a developmental point of view. Such patterns of energy distribution are probably general and diffuse in childhood and only gradually become specialized as definite activity patterns. The baby cries and reaches with his whole body for a desired object, whereas adult reaction shows a high degree of response focus. Every new skill that the individual learns seems to progress from diffuse general tension to activity concentrated in muscles used in that particular line of work. The child learning to write exhibits tension in all limbs. The skilled adult shows mainly finger tension in the writing situation.

Individuals probably differ in their rate of progress from diffuse general supporting tension to more specialized patterns of energy distribution. People said to be "poor learners" have been reported to benefit most from experimentally induced tension (5). This suggests that an uneconomical distribution of energy requires more total energy expenditure to accomplish the same amount of work turned out by

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the presumed well-patterned energy distribution of "good learners." Furthermore, effective tension distribution, once learned, will tend to keep total energy expenditure down to minimum levels. It is even conceivable that each person maintains rather stable habits of energy distribution, so that the proportion of aroused energy specifically focalized to that which remains general and diffuse might have diagnostic significance. Certainly, the most efficient homeostatic adjustment involves a low general-high specific tension differential (F.B. ratio). If, as we suspect, such differentials are due to acquired reactive attitudes the possibilities of learning in homeostatic adjustment is enormously increased. Any educator can appreciate what gains might result if more attention were given to teaching efficient energy distribution for work.⁵

Neuromuscular Homeostasis as Associative Learning. Having surveyed the effective conditions of acquisition and retention of new habits and adjustments, we are now in a position to examine learning theory. Theories of learning are roughly divided into two groups, the associational and the configurational. Arising first as explanation of particular types of learning series, each of these theories achieves an over-all physiological context only by implication. Argument turns upon the relative importance of contiguity and organization in fixation, and the importance of total homeostatic adjustment is all but lost sight of in experiments set to prove or disprove the primacy of specific learning conditions. When all the known facts are taken into consideration, it would appear that a modern formulation of associational doctrine best explains improvement in neuromuscular

⁵ A Mrs. Russell (private correspondence) has attempted to do this with her work on correct posture and breathing to support singing, speech, and the dance.

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homeostasis. Furthermore, configurational researches that stress the dynamic patterning of field factors seem best understood in the light of the associational hypotheses they seek to combat.

The modern formulation of the doctrine of associative learning recognizes the great plasticity of the central nervous organization, while still holding that some form of contiguous excitation is involved in progress from one version of homeostatic adjustment to another. When the organism is displaced by some internal need or externally initiated excitation, the entire repertoire of available responses may be called out until equilibration is adequately developed. In simple conditioning, an adjustive response is connected with a more antecedent pattern of excitation. In trial and error learning series, many different responses are tried and the tension-reducing one is fixated. This response need not be the "best" in terms of some logical criteria (witness the many back-endward solutions of the cat in the puzzle box, to say nothing of human compulsions), provided only that it is individually equilibratory. This fixated response is also associated with the external stimulus connected with its arousal, for the principle of the reflex circle (backlash action) gives to tension-reducing response the significant quality of "seeking more" of that stimulus (Holt's adience).⁶ Avoidance reactions (Holt's abience) become the negative phases of a homeostatic adjustment that takes the animal toward a more desirable and relaxing condition in physical space or in terms of internal equilibrium. Finally, those learning series in which the organism responds to relations between parts of a stimulus pattern (configurational learning) are also covered by association theory. For example, the insightful responses of Köhler's chickens to a relative

⁶ Cf. E. B. Holt, *Animal Drive and the Learning Process*, Holt, 1930.

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difference in brightness value might be referred to differences between the proprioceptive backflow of reaction to the two light stimuli. This would still provide a differential continuity to guide the animal toward the brighter light, even though absolute stimulus values changed.

The chief advantage of configural learning theory as now stated is its emphasis upon learners as energy systems. Its chief disadvantage is a lack of facility for quantitative measurement and for mechanistic interpretation. If we could measure the goals toward which the organism is said to strain, the needs which are said to be disequilibrating, precise physiological content might possibly be supplied for such concepts as "least action," "hypotheses," "insight," and other qualitative expressions of configural psychologists. But their continued isolation from modern physiological psychology results in a pointing to rather than a solving of the dynamic aspects of the learning process.

It would appear that a more exhaustive study of the neuromuscular adjustments made in learning (covert as well as overt) can supply the missing link between gross configural descriptions of organism-environment interaction and the more precise but limiting description of associational theory. Only when movement is regarded as an "overflow phenomena" and locomotion as the result rather than a contributory part of learning is association of present with past behavior lost sight of. The reactions of an experienced and hungry rat in a suddenly foodless maze are fairly convincing proof that the visual image of a food goal is the result as well as the cause of movement. It makes no difference in a given maze-run whether food is actually present or not, whereas any break in movement continuities between starting and stopping is markedly influential. No one who reads the literature carefully can

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escape the conclusion that response-produced effects serve both as drive and as cue stimulation. Such orientation indeed suggests new lines of research which may in turn relate the behavioral phenomena associated with effort in learning to the physiology of the proprioceptive system.⁷

The problem of "direction" is admittedly important in learning theory. As we get the energy sources of an animal's present behavior safely located inside its skin, movements appearing to be directed toward remote goals and distant ends are seen as largely forced from within. We cannot guess toward what these movements are directed or with what stimuli they are connected unless we know what has been reacted to in past situations. Knowing this, we can postulate that in the maze situation overt reaction of past eating has left a certain covert residuum which forms a part of the present field of excitation. Here the central nervous process identified with the eating set and reinforced by the excitation from the grosser hunger tensions presumably comes in contact with the visual excitation which represents the start of the maze. The interaction between these two parts processes is, by hypothesis, sufficiently like that holding for the earlier eating act for the aroused energy of the entire system to be discharged as a new set of overt movements directed toward the food end of the maze. This forced locomotion, a property of the dynamic interaction of exteroceptive and proprioceptive excitation, by discharging the aroused energies or tensions, begins building up a new tension system predisposing for specific later discharge. The tension-reducing response, focalizing on a background of relative calm, is presumed fixated and its threshold lowered for response to repetition

⁷ Cf. R. I. Solomon, "The influence of work on behavior," *Psychol. Bull.*, 45, 1-41, 1948.

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of a similar stimulus situation. The point to be emphasized is that the only continuities that matter in learning are continuities of movement, movement residua, or movement-produced stimuli, and not of such products as exteroceptively referred images of means and ends.

As psychologists come to give more attention to the peripheral aspects of traces of former reaction patterns, experimental fact will likely replace many of the gap-bridging concepts of associational theory. When an exact account of fixation of memory traces can be made, the problem of learning in neuromuscular homeostasis will be all but solved.

Some "Adjustment" Fallacies. Throughout this chapter we have avoided as much as possible the use of the term adjustment. This is dictated by its general abuse. There is no reason, of course, why one cannot talk of learned behavior as improved adjustment to a displacing stimulus situation, providing we have a true knowledge of the factors involved. Homeostatic behavior is mainly an adjustment to an internal upset; many times the external situation in which the aroused tension is discharged is irrelevant. Strictly speaking we adjust homeostatically to a combination of external and internal excitants and not to a single stimulus easily picked up by casual observation of overt behavior.

The adjustment concept is very questionable when we talk of good adjustment in terms of the external effect produced. This implies some standard of social approval or a value criterion. While it is possible for a person to be adjusted in this sense and at the same time be homeostatically efficient (discharging more stimulus-induced energy than is rearoused), it will be seen that in meeting many long-term and socially approved behavior standards, individuals often unbalance themselves homeostatically. Some of our best-

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adjusted men from a social standpoint are the most mal-adjusted physiologically.

The best-learned adjustment for civilized living is one that is homeostatically efficient at the moment and which will not involve a greater displacement later on because of its flouting of social taboos. It is a compromise between an immediate and highly personal tension-reducing act and an act which is more remote and socially constructive. The best of the social sanctions, by which men maintain their ability to live in groups, are those that are homeostatically adjustive to individual need from a long-term standpoint; that is, acts which will not harm others and hence bring about personal reprisals. Unless a convention meets this criterion, it can have little basis for retention in the mores; conversely, unless children growing up in such a culture are taught this compromise reaction, they will be a burden to themselves and to society. Far too often in the past training was concentrated only on the inhibition of natural homeostatic acts that have been judged socially inept or harmful. The "do as you like" school and "anything goes" philosophy of some progressive educators carried matters too far in the opposite direction. Today we are coming to realize that adjustment (physiological as well as social) is best when the child is taught "freedom within limits."

Discriminatory and Nondiscriminatory Behavior

The Problem of Psychological Functions. Years of psychological writing have been devoted to the description of such total behavior functions as sensing, perceiving, emotion, and thought; but these categories have not held up well under the impact of modern experimentation and neurophysiological fact. It is a commentary on their relative significance that topics once filling entire psychological texts can now be treated in a single chapter. Specifically, the homeostatic viewpoint concedes only two distinctly different types of total functional activity. One covers the nondiscriminatory generalized emergency adjustments of emotion. The other covers the highly discriminatory, specifically adaptive adjustments of perception and thought. Each of these types of exteroffective behavior have their own dominant neural control centers, their distinctive patterns of energy arousal and discharge, and their characteristic aftermaths of residual effects. In the well-equilibrated organism, discriminative functions normally dominate; nondiscriminative functions take over behavior controls only under sudden, unexpected stressful displacement or when the general energy level is held (because of powerful residual load) beyond the limits of effective discriminative

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discharge (optimal reaction range). The factors responsible for shifts from discriminative to nondiscriminative behavior and vice versa are the major concern of this chapter.

Nondiscriminatory (Emotional) Adjustment and Conflict. For many years it has been known that subcortical brain centers control the type of total homeostatic function known as "excited emotion." Motor centers in the thalamic region and its associated autonomic nerves show, when released from cortical inhibitory control, an increased excitability. Thereupon excessive generalized reactions such as snarling, weeping, and laughing, are frequently made to any and all external stimulus objects. From the standpoint both of overt expression and of conscious accompaniments, this generalized nonspecific adjustment is sharply distinguished from the highly discriminative response integrated by cortical control centers. In man especially, displacing stimulus excitation is normally carried to cortical centers, because of enforced inhibition of any lower motor centers in which crossover to action could have occurred. In the higher "delay paths" the differentiated and specifically adaptive pattern of neuromuscular discharge can be developed. However, in case the sensory excitation is too intense it may break over and set subcortical motor centers into action. An even more common cause of the subcortical breakover is presumably the indirect result of competition and conflict of existing excitation in the cortical control centers; that is, the conflicting excitation uses up so much cortical energy that these centers have little available to maintain their normal inhibition of subcortical reactions.

That conflict is a characteristic antecedent of the nondiscriminatory emotional type of adjustment was early recognized. Dewey and others (58) have emphasized the

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confusion, dissociation, and general disruption of specific adaptive behavior in emotional states; and Luria (105) has shown that the degree of such conflict in higher centers during stressful stimulation can be estimated in terms of the relative overflow of motor discharge (low F.B. ratio) into outlets that are nonspecifically adaptive. Of course, not all conflict in the traditional sense causes cortical confusion (with subcortical response by default of higher adaptive reactions). As was pointed out in the chapter on motivation, conflicts precipitating the relative loss of cortical inhibitory control over lower centers must be those demanding some *action* in order to equilibrate an internal disturbance. Always, one of the excitants must constitute a serious threat to organismic integrity. Many experiments confirm the importance of threat of physical injury, academic failure, loss of liberty, life, and reputation as conditions for release of emotional discharge. "White lies" which are unmotivated by the necessity of self-defense do not develop significant emotional reactions.

Without here entering into the exact mechanics behind release of cortical dominance in conflict, one can easily appreciate that a severe intracortical competition of neural impulses will leave less nervous energy available for control of the subcortical centers. The cortex maintains a very unstable dictatorship over lower-order behavior. When seriously taxed with incoming stimulation, it has to give up some of that control. This leaves the lower motor centers relatively free to initiate the more primitive nondiscriminatory responses of excited emotion at the very time when the higher centers are having difficulty in fashioning a highly discriminatory, specifically adaptive discharge. In other words, total emergency flight or fight reactions tend to function in equilibrating stimulus displacement when

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nothing better is forthcoming. Thus, after some fashion, is organismic integrity preserved.

Energetics of Emotional Response. So much attention has been given to attempted correlations between physiological indices of diffuse bodily arousal and conscious "emotional states" that researchers have all but lost sight of the energetics problem. For instance, studies that fail to show any physiological differentiation between stimuli judged as "pleasant" and "unpleasant" do tend to indicate that the degree of experienced intensity of a displacement (regardless of its meaning) is reflected in measure of general bodily arousal, such as blood pressure, respiration, and skin conductance (11, 27, 86). Another experiment pertinent to the homeostatic viewpoint indicates a high correlation between extent of skin conductance change and reports that the organism is attempting to overcome an imaginably recalled predicament or difficulty (1). This and much other work on bodily changes in emotion bears indirectly on questions of energy mobilization and discharge. So-called "emotionally toned" stimulus words, which produce greater physiological upheavals than "neutral" words, are simply displacements that spread their effects to involve general diffuse self-maintaining bodily reactions rather than limited and specifically adaptive ones. Physiological recovery (R.Q.) from "emotionally toned" stimuli is a function of the intensity of emotional reinforcement. Blocking a specific channel of overt discharge, as in frustration studies, tends to produce generalized reaction of subcortical (emotional) origin. Everywhere one looks in the whole vast field of "expressive studies" there are suggestions of emotion as a type of diffuse generalized equilibratory action, serving to discharge peak loads of energy arousal.

Emotional Discharge as Homeostatic-Regulation. Although

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generalized rather than specifically adaptive, emotional discharge is homeostatic-regulatory. The hypothalamic control centers mobilize the body's resource for violent physical effort and dominate total behavior in emergency situations. Emotional discharge may extend over the entire effector apparatus, giving rise to skeletal, visceral, and glandular response. Normally, however, cortical centers are still able to maintain a good deal of inhibitory control over skeletal responses, with the emotional discharge characterized by relatively unchecked sympathetic nervous reactions such as those involving shivering, bladder tension, and heightened blood pressure.

All aspects of emotional discharge, from the limited but diffuse skeletal reactions to the more intense neurocirculatory effects are exhibited in the *startle pattern*.¹ This primordial type of generalized motor reaction offers a basic approach to problems of emotional discharge. It is homeostatic-regulatory in that it rids the system of a large amount of excitation aroused by sudden, intense, unexpected stimuli; furthermore in terms of its general backlash from smooth muscle and glandular activity, it readies the system for more violent physical effort in either combating or getting away from the displacing source of stimulation. The startle pattern tends to be the same for all types of unexpected stimulation. It presents wide individual differences in extensity and intensity of reaction. Its skeletal aspects are much reduced in adults; but its neurocirculatory aspects cannot be set under voluntary control and are therefore very useful in the detection of guilt. Small wonder, then, that the startle reaction is an extremely valuable aid in the study of factors influencing neuromuscular homeostasis. Later we shall see there is much to commend

¹ C. Landis and W. A. Hunt, *The Startle Pattern*, Rinehart, 1936.

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the use of this reaction in psychophysiological diagnosis.

It is readily appreciated that the acute startle (fight and flight) reactions are homeostatic-regulatory in discharging excitation aroused by sudden, intense stimulation.² The equilibratory values of chronic states of long-maintained visceral tension are not so well understood. At first glance it appears that these emotional reactions are the reverse of good homeostatic adjustment, and from one point of view they are. Certainly they are not as equilibratory as skeletal or even verbal avenues of motor discharge, and they tend to increase in direct proportion to the closing of more active channels of outlet. But they are better than nothing. Without them the organism would at times destroy itself.

When an irresistible force meets an immovable object, something has to give way. This is exactly the condition the organism sometimes finds itself in when a powerful displacement comes up against a powerfully developed inhibition to equilibratory skeletal action (as with the desire to kill an adversary in anger or to commit suicide in acute disappointment and failure). Without the visceral relief valve, unhealthful and self-maintaining as it may be, the organism would tend toward rapid disintegration, either by giving way to self-destructive acts or by adopting the complete disorientations of the psychotic personality. "Sweating out" a difficulty by way of visceral emotional discharge often helps keep a large part of the organism's potential energy available for routine homeostatic adjustment, both discriminatory and nondiscriminatory. The man who lets an acute worry about his job-security settle through

² M. B. Arnold has argued (*Psychol. Rev.*, 5, 35, 1945) that anger and fear have no "emergency" function (as does flight); but this neglects their preparatory values. For the influence of activity level changes in emotional motivation cf. E. Duffy, *J. Gen. Psychol.*, 25, 285-297, 1941.

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his visceral organs may still be able to sleep, eat, and avoid the common dangers of life. Tomorrow or the next month may find the external situation or himself more favorable to making a specific skeletal discharge which is both directly expulsive of the old irritant and yet not inimicable to his other and long term homeostatic demands. Here the chronic tension served both as partial relief in a period of acute stress and (because of its backlash effects) also as constant reminder of the necessity for effecting a better adjustment.

The greatest homeostatic disadvantage of an emotionally maintained visceral tension is that it can become chronic, that is to say, a habitual way of responding to any and all types of disturbance. Less physiologically desirable than the skeletal discharge of general emotional excitement (low R.Q.), it is often a highly desired temporary expedient in terms of larger wholes and long-term homeostatic demands. Where training has favored an overdeveloped inhibition of skeletal overt and verbal discharge, it is about the only peripheral relief that is open. But if somatic types of emotional discharge are used to the exclusion of normal (but inhibited) skeletal accompaniments, they tend to carry more and more of the expressive load of all emotional crises. Finally, the organism gets where it discharges generalized emotional excitement through no other channels. Even in displacing situations where word or action would not harm long-term organismic integrity (as in kicking an obstructing chair out of the way or in arguing politely with a recalcitrant customer), there develops a tendency to "take it all out through one's own insides." Somatic emotional discharge at this stage has passed the point of moderation. It is no longer contributory (principle of supplementation) to total homeostatic adjustment. It is a destroyer and not a creator of equilibrium.

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When one begins to worry about a chronic headache instead of the displacement that caused it, this might be considered a sign of overreaction, an indication that somatic discharge has gone too far. Return to the inhibited outward manifestations of emotional reaction (weeping, ranting, and pacing) may be a cure.

There is even evidence that as chronic emotional tension settles in particular organs like the heart and stomach, this forms the basis for an organ neurosis. Whether the organ utilized for overflow emotional expression is the strongest in the entire system (rising to take on more work besides its own) or the weakest (unable to resist the onslaught of unchannelized nervous excitement energies) cannot be settled at this time. It does appear that people tend to fall into somatic subtypes both on the basis of hereditary weakness (as when incipient heart trouble is brought on by emotional strain) and developed strength (as when a singer or speaker localizes emotional tensions in the larynx or respiratory system). Much more could be written of the danger of confining emotional discharge to somatic-visceral part-reaction systems, but this is beyond our present inquiry. Here we are mainly interested in pointing out that limited amounts of covert emotional response serves homeostatic purposes, just as do the more obvious and overt expulsions of excited emotion.

Theories of Emotion. We are now in a position to review a controversy of long standing in the field of emotion, namely, the relative importance of central and peripheral processes in developing the emotional consciousness. The central view was given early formulation by Ladd, who spoke of emotion as "a sort of nerve storm in the brain, whence there descends an excitement which causes commotion in the visceral and vascular regions, thus secondarily induc-

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ing an organic reverberation." The alternative peripheral view has had its chief sponsors in James and Lange, who regard the central (and experimental) processes of emotion as secondary to an immediate bodily reaction to the exciting stimulus. Today the majority of psychologists are given to uncritical acceptance of the central theory as developed by Head and Cannon, and much time is spent in arguing the priority of central nervous discharge over peripheral factors, that is to say, which comes first, the chicken or the egg? The controversy, however, has been productive of research, and this must be evaluated before we can bring the good points of both sides within the homeostatic framework.

According to peripheral theory, visceral reactions produce the emotional consciousness, that is, we are afraid because we run and angry because we feel our stomachs quivering. The exciting stimulus breaks over reflexly into diffuse bodily reactions, and the backlash excitation of these discharges furnishes the emotional tone of the whole experience. Such a statement has not gone unchallenged, and various experimenters have attempted to show that complete elimination of afferent (backlash) impulses from the viscera still leaves an animal behaving as emotionally as ever. Others have produced visceral reactions by injection of adrenalin, but without genuine emotional experience.

As increasing doubt was cast concerning the adequacy of peripheral theory, the discovery of hypothalamic centers of emotional discharge was seized upon as a basis for a central theory of emotion. According to this theory, afferent impulses initiated by the external stimulus excite the thalamus, directly or through the cortex, and this sub-cortical organ, in discharging explosively, not only de-

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velops the efferent pattern known as the "expression" of emotion, but also discharges centrally to the cortex, adding the peculiar emotional "quale" to the original stimulus excitant. In this theory the peripheral discharge has no backlash function; it is an overflow phenomenon, a reverberation from central confusion and nothing more. Though right about the central control process, it is wrong in failing to make peripheral reactions contribute something to the central nervous flux.

It should be pointed out that both central and peripheral theories recognize the reality of emotional discharge and emotional experience. And the controversial issue as to which comes first is a scientific will-o'-the-wisp, especially in view of the indications shown earlier that central and peripheral processes are inseparably linked. Our homeostatic account of emotion avoids this central-peripheral issue by recognizing that thalamic motor discharge and backlash interoceptive excitation therefrom resulting are both parts of a total circular process essential for emotional experience; that is, when exteroceptive excitation breaks over at the thalamic level, backlash effects from its motor discharge flood the cerebral cortex with a mass of diffuse interoceptive excitation that interacts with the already existing exteroceptive excitant to develop the emotional experience. In the startle pattern it is a matter of a split second as to which comes first, the motor discharge or the experienced feeling. Therefore there is little to the argument that visceral processes aroused by thalamic discharge are too slow acting to provide a basis for emotional experience. This does not mean of course that visceral actions by themselves can generate the different emotional experiences of rage, anger, and fear. As we shall find with the specific discriminatory-reactions of object perception, emotions can

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be regarded as different meaning structures, produced by an interaction in the cortical field between the exteroceptive (external) excitant, specific proprioceptive residuals from learned reactions made to this and similar displacements in the past, and diffuse generalized backlash from unlearned thalamic discharge. The middle factor in this dynamotor equation is far too often ignored in theories of emotion. The specific set-expectancy of an act already in progress or recently completed is very important in determining the meaning of the so-called emotional excitant. For example the same stimulus may evoke either fear or anger, depending on whether we are already predisposed toward making reactions habitually associated with one or the other of these meaning structures. Often we do not feel afraid of a truly threatening stimulus because we are reacting in anger to something else. On the other hand, when we are in an apprehensive posture a harmless stimulus can cause us to be paralyzed with fear. Much is to be gained by thinking of any emotional experience as a highly complex meaning structure developed by backlash (specific and general) from reactions made to the external stimulus displacement to which the meaning attaches. Peripheral—visceral and central—thalamic processes are then seen as inextricably bound together in fashioning the diffuse discharge that forms a basis for all emotional experience.

Discriminatory Adjustment and Discharge Control. It is generally agreed that the cortical brain centers control those specifically adaptive functions usually referred to as sensing, perceiving, thinking, and imagining. A single descriptive term, *discriminative adjustment*, can be applied to all such categories. Just as perception is a higher order of sensory discrimination, so thought and imagination build upon the residuals of past-perceiving, combining these in

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new and original ways. All such reactions to displacement require a high order of discriminative capacity, an ability to respond differentially to nearly identical stimulus patterns. But specifically adaptive adjustment requires something beyond an ability to make fine sensory, perceptual, and imaginal distinction; it implies a cognate ability on the motor side of the reaction arc as well.

When two distinct stimulus effects are simultaneously operative within the organism, incompatible part-reactions tend to be made to each. In order to fashion total homeostatic adjustment along the most highly adaptive lines, some part-reactions must be inhibited while others are enhanced. This calls for cortical direction over any and all pathways of motor discharge. The problem is further complicated by the fact that a single stimulus excitation often tentatively excites two or more mechanisms of motor discharge. It means that in order for a particular overt discharge to emerge, other and less adaptive ones must be actively inhibited.

Such narrowing down of the motor outlet is not done by external stimulus controls, but by internal ones. We need to think of specific adaptive behavior as due to the interaction of two distinct central nervous factors, one (discriminative capacity) operating primarily on the sensory side, the other (discharge control) operating primarily on the motor side. It is thought that such factors are independently variable. Certainly, clinical data would support the contention that many persons have discriminatory capacity without discriminatory adjustment. They sense the true nature of a displacement or need, but are unable to develop the control of overt reaction necessary to fashion the most specifically equilibratory response.

Neurological evidence would center the directive dis-

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charge control factor in frontal lobe function since face-tiousness and excessive emotional discharge through lower centers are characteristic of animals and men deprived of these brain centers. Discharge control is most easily established from higher to lower motor centers, and many may think the function ends here. But a moment's reflection convinces one that this is really only the beginning of an ability that can develop finer and finer controls within the framework of cortical integration itself. Witness the struggle an individual frequently goes through in finding the precise word, the precise action that best fits a particular situation. Note also that some people seem always to say and do the exactly right thing, whereas others are clumsy, tactless, and ill-advised. We shall leave till the next chapter this problem of individual differences in discriminative adjustment through discharge control and proceed to its several other aspects.

Role of "Set" in Discriminatory Adjustment. The way in which the neuromuscular system functions to channelize excitation into specifically adaptive motor discharge is most conveniently approached by the study of set-expectancy. As used in the present context, the term "set" covers the covert tensions of the skeletal musculature that are antecedents (also consequents) of overt reaction, together with their central backlash effects. At any given moment the organism is exposed to a great complex of internal and external excitants. Were each connected with its own private motor discharge mechanism, it would be theoretically possible to equilibrate each effect individually. But afferent channels are five times as numerous as efferent channels and central nervous organization is such that all efferent nerves share the control of the entire motor mechanism. Consequently, without some internal regulation there

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would be an indiscriminate diffusion of energy discharge through all the effectors. This regulation is provided by a narrowing down of the neural flux in prepared central (adjustor) and peripheral (effector) channels.

That psychologists have long recognized this selective feature of discriminatory action is indicated by their use of such terms as *set*, *einstellung*, *aufgabe*, determining tendency, predisposition, frame of reference, and behavioral environment. These terms indicate that the organism is never neutrally disposed to the various environmental

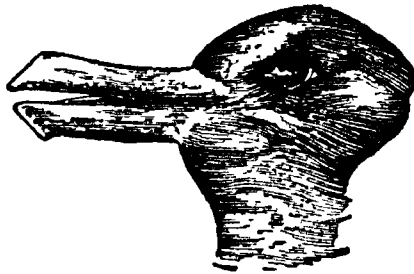


Figure 8. The duck-rabbit figure. A favorite with psychologists to show the influence of set, angle of regard, and so forth, in discriminatory response

agents that act upon its receptors. Instead, it has various ways of taking the stimulus, ways which anticipate and determine the ultimate form which overt response will take. A man may glance at the figure produced above and see either duck or rabbit, dependent upon the way he is set or predisposed. If he has recently been hunting waterfowl, he may call it a duck; if a pet fancier, the "rabbit" reaction may be made. Similarly, individuals will adjust differently to the sight of a wooded park, according to their particular thought set or frame of reference. The realty agent will see it as a potential subdivision, the nature lover as a bit of woodland to be preserved intact, and the entomologist as a breeding place for mosquitoes.

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What the organism can do at any given time is very much limited by its postures at that time. These postures are at first the diffuse muscular tensions of general alertness, maintained largely by continuing interval needs. Under learning they soon change to specific expectancies which the organism assumes with reference to associated external stimulus objects. Whatever their initiating cause, these sets act as selectors by narrowing down available channels of overt discharge for stimulus-induced displacement.

There are two aspects to the problem of response selectivity, and peripherally maintained sets and postures are essential to an understanding of both. Sets not only aid in preparing particular channels for the discharge of externally initiated excitation but they also help to close otherwise available channels of discharge. We have seen that the higher nervous centers have the capacity to inhibit as well as to excite overt skeletal responses; both these central processes can be aroused and maintained by peripheral sets. The peripheral maintenance of a given central discharge channel is exemplified in its simplest form in reaction time experiments by the antecedent tensions in arm muscles that are to react overtly when a given external stimulus is applied. Here the set is the tentative response-to-be. The terminal action of the muscle is already in progress, and its backlash central excitation aids in lowering the threshold of the motor pathways over which the "anticipated" stimulus excitation will discharge. But the organism may be set *not* to make a given response; this, at its simplest, takes the form of a covert preparation to make an antagonistic reaction, as when the organism's set "not to lift the hand when shocked" appears as a set to "press down" on the shocking plate. Such a set develops both terminal inhibition (as an antagonistic muscle group is

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thrown into action) and also backlash central inhibition of the motor pathway (as would be normally excited by the awaited stimulus).

These instances of facilitative and inhibitory sets show analogous terminal and central effects. But in the more elaborate preparations for or against a given response, the maintaining peripheral process may not be located in the same or adjacent muscles as would be involved in that response; that is, the covert set-response may exert its influence on the overt response mainly through its central backlash action, as when tension of the stomach lowers or raises the threshold of a skeletal discharge pathway according to whether the stomach-set has backlashed to arouse excitatory or inhibitory pathways within the cerebral cortex. We are entering here, of course, upon a highly speculative field of neurology. Yet the necessity for some such construct becomes more obvious as we examine the experimental evidence on the modifying influence of both general background muscle tensions and focal muscle "sets" on subsequent overt response.

Studies in Focal Set-Expectancy. That specific set-tensions, mobilized in anticipation of a particular displacement, are influential in channelizing overt discharge along highly adaptive lines has already been indicated in the study of set-expectancy in the conditioning of the dog (57). Many other experiments have surveyed the influence of focal set-expectancy in learned discriminatory response. It has been shown that the pattern of covert muscle tensions mobilized to a warning cue is more diffusely localized for "sensory reaction" than is the so-called "motor reaction" set (45) and that the greater the speed and effectiveness of the motor reaction over the sensory type is the direct result of its highly focalized preparatory set. Such channelizing effect

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influences reflex as well as voluntary action; the eyelid reflex is facilitated more by instruction to make a voluntary wink (focal set expectancy) than by a set localized in more remote (finger) muscles (117). Finger oscillation is most rapid when experimentally induced tension is localized in the reacting muscles and least rapid when the antecedent tension is localized in anatomically remote muscle groups (48).

Actual recording of concurrent covert activity in several muscle groups before and during discriminatory response has shown differential patterns of tension. In reaction time experiments, delicate levers placed over the four limbs revealed greatest antecedent activity in the muscles which the subject was set to use in making a particular response (45). When instructions first given to make discrimination reaction with the fingers were shifted to instruction to prepare to make foot reactions instead, the focal tension shifted from arm to leg muscles in accordance with expectation. More recently the special distribution and foci or covert set-expectancies have been studied by use of the action-potential technique (20, 32, 34). Simultaneous recordings from a number of muscle groups indicate that, as an individual is set to perform a given act, muscular involvement decreases with the distance from the member indicated as focal by instructions. Sets for different kinds of activity, such as weight-lifting and typing and mental arithmetic, show different distributions of muscular activity (116). In another study, tension in different muscle groups was found to vary with the type of performance anticipated; for multiplication, the focal set was in the right arm, while for the learning of nonsense syllables, neither arm showed greater focal activity (32). Explanation for such a difference was suggested by subjects who

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reported that they had a strong tendency to write down the multiplication answers. Inasmuch as the reliabilities of these differences in tension pattern are low, it would be premature to assume that every distinct discriminatory act has its peripherally unique set-expectancy pattern. Many similar reactions could be supported by equivalent peripheral sets; and the more complex the activity, the more would these patterns vary from individual to individual. For example, there is little individual difference in the focal musculature involved in the typing set, and a great deal of difference in those involved in problem solving. According to reports collected from famous writers and thinkers, there is no standard posture or set essential to efficient creative work. Some persons, as a matter of habit, prefer prone or sitting positions, but they can and frequently do work in other postures as the occasion demands.

Action potential studies of "einstellung" in successive comparison judgments (weight lifting) have contributed to the understanding of set expectancy, especially in the optimal time relations for superposed stimulus effects (126). Similar action potential records have also been used to study the underlying energetics of the optimal warning interval in reaction time experiments (33). Intensity of prior set changes the optimal warning interval (74), so that timing, amount, and locus of antecedent set-tension are all found important in the channelizing of specific discriminatory discharge.

One of the clearest instances of the importance of antecedent focal tensions in neuromuscular homeostasis is shown in the study of tension patterns in the startle response. When a warning cue signals that a particular limb of the body is about to receive an electric shock, tensions developed in that part prepare the organism to "take it"

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(45). When the shock stimulus falls on a background of no specific pattern of set-expectancy, consequent overt activity is much more extensive and intensive than when antecedent tension is centered in muscles specifically utilized in the equilibratory withdrawal act.

Analysis of such studies as have been mentioned above appears to lead to the following generalization: *Set-expectancies are tentative and antecedent homeostatic adjustment acts, developed in response to minimally displacing stimulus cues and preparing the channelization of discharge through some particular response outlets which, if not so prepared, would function only through a greater displacement to general equilibrium.* In other words, this preparation of the central and peripheral channels of equilibratory discharge keeps the excitation aroused by the awaited stimulus from overflowing into nonrelevant discharge mechanisms and so contributes to the conservation of energy. Hence we have a metabolic as well as a neural control differential between discriminatory and nondiscriminatory response.

Principles of Tension-Set Patterning in Discriminatory Response. Investigations of the tension-set patterns that accompany and sustain specific equilibratory action reveal the operation of at least seven related principles. These are summarized below in order to point up procedures for investigating the energetics of prepared action.

1. Prepared discriminatory reaction involves slight general increments in the tension of the skeletal musculature. Any apparent reversals are due to let-downs during performance and failure to secure a proper baseline (basic energy level) before beginning the test.
2. Tension patterns antecedent to a given task tend to have a focus in some particular region of the body. This focus differs with the

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type of discriminatory response anticipated and with the subject involved.

3. Tension patterns which support different overt equilibratory sets have varying degrees of spread. Some concentrate largely in one muscle group while others are widely diffused. In general the more specific focus of the muscle preparation the less the tension spread to other muscles.

4. Tension patterns show a gradient of lessened magnitude of activity in the muscles with increasing distance from the focal part. The steepness of this gradient is inversely related to degree of spread, for a highly localized pattern will tend to show greater increments at its focus than will patterns that spread over other muscles.

5. Muscular activities forming a part of the same tension pattern tend to vary concomitantly; that is, they increase and decrease in response to the same stimulating conditions.

6. The focus of the antecedent tension pattern tends to be identical with the working tension involved in overt response. Other things being equal, the greatest antecedent tension develops in the part to be utilized. This principle of response specificity holds most clearly in a limited reflex act, and tends to follow habitual lines in more complex acts such as arithmetic computation, where the channel overt reaction (verbal, written, etc.) is itself varied.

7. The total amount of excitation developed by an antecedent tension pattern will have facilitative effects to the degree it is related to both the peripheral and central aspects of the overt equilibratory response. Within limits, the more specific the focus of preparatory tension, the greater will be any facilitative effect that may derive from compensatory increments in general tension background. Tension experimentally induced in nonfocal parts of an equilibratory reaction pattern will tend to facilitate performance of the focal part until spread therefrom raises the general excitation level beyond safe limit (optimal reaction range concept).

Most of the principles given above can be illustrated by reference to the diagrams below. In Figure 9, the baseline represents the spread or number of muscles involved in a

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set-tension pattern. The vertical dimension of the diagram represents the amount of overt activity in the involved muscle groups, while the curved line connecting these points indicates the relative concentration or diffusing of the tension pattern. The total area under the curve represents the total energy expenditure or effort involved. Diagram A illustrates the presumed type of tension pattern that would precede and accompany finger reactions when the subject is set to make a specific adaptive movement to a specific stimulus displacement. While there is slight

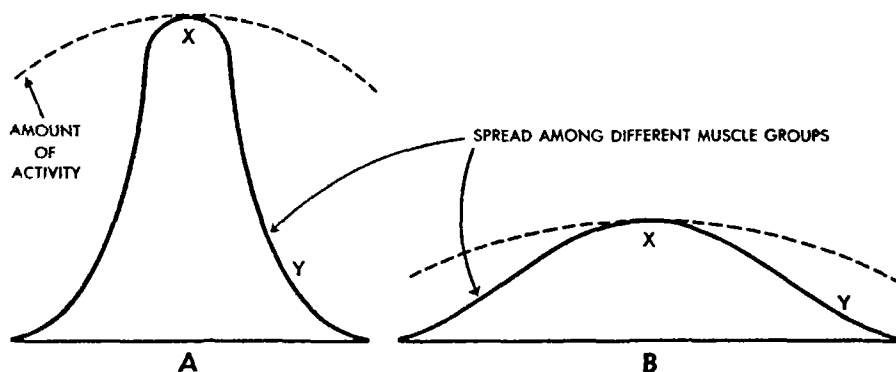


Figure 9. Tension patterns for different types of action. A. Finger oscillation B. Mental arithmetic.

increment in tension throughout the musculature here, the main concentration is in the muscles primarily involved in the focal-overt response. On the other hand, the presumed tension-set pattern for mental multiplication, as seen in Diagram B, differs in marked respect from that of finger reaction. While its focus may be in the same general muscle group as in A (due perhaps to habitual writing movements of that part), the tensions are much more diffused; not only do they spread over more muscles, but the gradient is less steep in B than in A. Another difference between the tension patterns B and A cannot be illustrated

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by diagram; whereas the principle muscular focus tends to be constant for finger reactions within the same and between different subjects, the tension focus for multiplication tasks may vary. Since the stimuli it anticipates (an unknown series of digits) are changeable, a more specific set-expectancy cannot be developed. Tensions accordingly shift among various muscle groups in the same and different subjects (30).

Because of differences in the pattern of focal tensions, general excitation background effects also vary with type of task. The principles governing these interrelations may be illustrated by reference to the diagrams. The dotted line (a) represents the upper limit where tension distributed in the manner indicated would facilitate finger reaction (optimal reaction range) (A); the dotted line (b) represents a similar optimal level for the total tension set pattern of mental multiplication (B). The difference between these dotted lines and the solid line representing normal focal tension accompaniment of acts A and B indicates that mental multiplication (B) will suffer sooner from progressive increments in general tension than will finger reaction (A). However, if a comparable but small amount of tension were induced in the same nonfocal muscle (Y) for both tension patterns, it might spread its effects more advantageously to multiplication activity B than to finger reaction A; that is, since the gradient between focal muscle X and nonfocal muscle Y is less steep in B than in A, tensions induced in Y might not affect the focal part of A to any great extent, but would aid markedly in raising focal tensions of B to a higher level. Already there is some evidence that reflexes such as the eye-wink are markedly influenced by tensions induced in some remotely connected muscle group, whereas the learning of verbal response is

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facilitated by tension increments in the same part. An important problem for future research lies in determining the differential effects on various tasks of set-tensions induced in the same locus and amount.

Theories of Set. The concept of set plays such an important role in all discussion of discriminatory reaction that a consideration must be given to factors presumably responsible for its selective function. There are two general theories. According to the first or *peripheral* type, set represents a tentative implicit or anticipatory stage of a response that is to be made overtly to ensuing external stimulus. According to the second or *central* type of theory, set phenomena are strictly cerebral, and any motor accompaniments are only overflow phenomena. Both theories have certain merits as well as defects.

In its simplest form, peripheral set theory supposes that when the organism prepares for specific discriminatory reaction, only a part of a larger stimulus pattern (such as the instructions) is active. Hence the appropriate adjustive response cannot fully emerge, it must exist in a tentative overt state until the complete stimulus pattern appears. In other words, the first stimulus is not sufficient to raise reaction to overt threshold strength; but it does tentatively excite the same peripheral discharge pathways that are aroused by the completed stimulus pattern. When the rest of this pattern acts, afferent nervous excitation summates with those already in existence to produce overt response. Sets, then, are not a particular class of phenomena but a nascent form of the discriminatory response that they anticipate. In such an analysis, the awaited stimulus becomes nothing more than a trigger, releasing to full potency an activity already in progress. It does not change or contribute anything to the character of the covert reac-

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tion pattern, but merely increases the strength of this pattern so that what was implicit and covert becomes explicit and overt. This notion is especially attractive in explaining the selective action in certain types of discharge. For example, when the car driver is watching for the traffic light to change, he is already responding implicitly, tentatively releasing the brake and reaching for the clutch pedal; impulses aroused by the green traffic light merely accrue to this motor discharge pattern and intensify it to overt strength. If similar analyses could be successfully made for all types of response discharge, this theory would have little to condemn it. In many cases, however, antecedent excitatory patterns are qualitatively unlike the subsequent response—set conditions not being limited exclusively to the muscles involved in focal part-response. In many instances the organism gets set by adopting a general posture that will select and sustain a whole class of overt responses. This postural set is not a tentative rehearsal of the specific response-to-be.

Central theories of set gain most by default of peripheral theory to show differential motor accompaniments of predispositions and determining tendencies whose selective influence appears mainly by way of the conscious aspects of discriminatory response. Typical of the central explanations are Titchener's free use of such terms as "cortical set," "nervous bias," and "neural determination," and the assumptions of many gestalt psychologists of centrally maintained reaction dynamics. However, this is really only dumping the problem into the laps of the physiologists and does not adequately take into account the known facts of motor processes in higher-order behavior. Some experimental defense of central theory has appeared (112), but examination of a typical report reveals certain inadequacies.

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This study shows that motor reactions to a tone stimulus are slower if it comes after a series of reactions to light than when it follows a series of tones. The fact that the motor response is the same for both types of stimuli is said to argue for a central expectancy or exclusively neural set. However, these shift experiments would have permitted differential motor adjustments of the reactive sense organs. The lengthened reaction time when tone was presented upon a background expectancy for light might have been due to the unprepared state of the tension tympani and other and more general muscular preparations favoring hearing, rather than to an exclusively central factor.

It would seem apparent to all who study the evidence carefully that the locus of set is neither exclusively central nor peripheral. Granted that tension in a muscle will facilitate its overt reaction to excitation of other origin (peripheral effect), the fact that this muscle gives rise to backlash proprioception will also presumably create a differential patterning of the brain state (central effect). Here, just as with other phenomena of total homeostatic adjustment, it is futile to attempt a separation of central and peripheral effects. Both types of theory are, therefore, best combined into one which recognizes the interaction of nerve and muscle in the determination of response selectivity.³ According to this approach, the basis of a central expectancy is backlash excitation from outlasting postural adjustments previously made to the stimulus anticipated. If different types of response discharge (vocal motor, somatic) were to be made to the stimulus anticipated, the focal tension

³ A more comprehensive discussion of set theory will be found in G. L. Freeman, "The problem of set," *Amer. J. Psychol.*, 52, 16-30, 1939, also *J. Exp. Psychol.*, 26, 622, 1940, and R. C. Davis, "The psychophysiology of set," in *20th Century Psychology*, Philosophical Library, 1946.

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would shift to the part to be activated. However, if the same overt reaction were to be made to several classes of stimuli, slight changes in the nonfocal aspects of the tension pattern (such as reflex sensory adjustments) would be sufficient to establish (principal of backlash action) a central condition of lowered threshold for the stimulus about to be presented. The more specific the muscular preparation, the more differentiated would be the anticipatory central pattern but, even in the case of so-called "mental acts of directed thinking," motor adjustments would play a selective role, either by narrowing down the range of stimuli to which the subject was set to respond, or by providing a sufficient general excitation background that could be organized centrally for the facilitation of selected responses. As we shall see in the next section, there is considerable reason to believe that differential motor adjustment lies at the base of most of the highly discriminatory perceptual and thought meanings.

The Response Basis of Meaningful Discrimination. It is the reactions made to objects of vision that are largely responsible for organizing sensory excitation into meaningful perceptual patterns, not the objects themselves. Numerous reports have shown that the motor residua of past reactions, such as ways of looking or moving in reference to external stimuli, form essential parts of the field of present perceptual excitation. For example (42), several different perceptual meanings can be referred to the same ink blot if it is presented in positions favoring different ways of looking, or if the human subject is specifically directed to react to different side-details in the figure.

This difference in angle of regard and response to detail is, of course, the basis for the shift in meaning-structure in reversible perspectives. Gestalt psychologists have used

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these drawings to demonstrate that shifts in "figural" perception depend upon "ground" factors; but they ignored the important role of background motor adjustments almost completely, wrongly referring such total properties as "meaning" exclusively to an interaction of figure and ground subparts within the area of visual excitation. Their accounts of reversible perspective tell only that wholes change after the fact. They do not predict the part condition necessary for each new meaning structure to emerge. They give a splendid account of *what* we perceive, but their description of *how* we perceive is very incomplete. The unitary character of original experience in the child is wrongly referred to the mirroring in the brain of already existing and more probable analogous stimulus organizations. The reason why a child sees global totals without learning is because of reflex motor adjustments, backlash excitation from which interacts with the exteroceptive sensory flux in the brain field. Further perceptual differentiation depends upon additions to this "core" by learned motor adjustments.

Experiments on the development of object perception have shown that different types of global total tend to condition different types of eye movement and angle of regard. For example, many of our common object perceptions like a pine tree or umbrella suggest unidimensional spread and are reacted to by a particular way of looking. The meaning-structure of the total excitation pattern refers, of course, to the source of visual excitation, for the motor adjustments we learn to make in discriminating fine difference in the visual field are not the meaning, *per se*. There is no "dog" response, as such; dogness, in the response theory of meaning, is the product of equivalent ways of looking at sets of equivalent visual objects. But there is

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no perceptive meaning in the absence of these ways of looking (or their surrogates), and the more particularized these reaction tendencies, the more differentiated is the meaning-structure.

Five general principles can be deduced from the study of perception, all having important implications for discriminatory response. These are *modal focus*, *induction*, *surrogation*, *selection*, and *shift*.

1. *Perceptual integration is usually built around one particular mode of sensory excitation*, but is never made up exclusively therefrom. The one common and universally present type of excitation is proprioception from the muscles participating, explicitly or implicated in the equilibratory response.

2. *Contributory sources of perceptual integration are induced by the modal excitants*. This is readily illustrated in the empathic motor responses, which help contribute the aesthetic meaning of properly balanced visual objects.

3. By continued association *the modal excitant tends to become the surrogate for effects originally conveyed by other part-reactions*. A typical example is the "soft look" of velvet. This qualitative meaning, originally contributed by motor and tactual impressions, comes in time to be carried by the visual excitant due to stimulus substitution or conditioning. Because of this we are seldom aware of looking or reacting to a visual object in a particular way.

4. *Perceptual integration is always a selective response*, representing only a part of the available afferent excitation. Motor adjustments aid greatly in reinforcing one group of sensory stimuli and the neglect of others; thus, in the final analysis, response is the selector and integrator in discriminative adjustment.

5. *Perceptual integrations shift and displace one an-*

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other with ease, especially since they are only partial and selective groupings of available afferent excitation. While this shifting is probably related to the competition and rivalry of concurrent neural excitations, we must not neglect the fact that one of the main reasons is the relative fatigue of the motor processes which help to hold one group as the focal respondent to the exclusion of other stimuli. The case is easily seen in reversing perspective. Traditionally speaking, shift is usually referred to the power of attention. This conception, however, has always been the stumbling block of systematic psychology and we shall do well to avoid it. We can force ourselves to give in to relatively weak stimulus displacements largely through reinforcement by particularized motor adjustments. When such motor adjustments become habitually aroused by certain classes of stimuli (as with the specialist), psychologists speak of the individual as having attained the state of derived involuntary attention.

The Energetics of Effort. This topic covers the maintenance operations by which the organism can hold itself to specifically adaptive discriminatory reaction in the face of distraction, fatigue, and other disruptive influences. The learned reactions of perception and thought are easily fatigued and readily upset by major displacements to organic equilibrium. In order that the discriminatory line of response may be held and the return to nondiscriminative emotion prevented, new resources of energy must frequently be summoned. This is made possible by self-reinforcement (compensatory mobilization). When the organism mobilizes to meet a stimulus displacement, the original energy quantum is a function of the anticipated difficulty of the work and the intensity of the displacement to be equilibrated (4, 8, 17, 62, 85). The more difficult the

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task, the more anticipatory tension is aroused (61); the faster the rate of performance, the more energy is mobilized (114). In many instances, however, the original energy quantum is not sufficient to effect an adequate discriminatory discharge. This is particularly true if additional demands are made through the introduction of distraction or by protracting the work period. But so finely adjusted are the homeostatic mechanisms of higher order behavior that a weak discriminatory pattern of adjustment can still dominate the adjustment apparatus; through its "prior entry" it can command additional reinforcement from the muscles and other general energizing processes. Compensatory increments in muscle tension have usually been found in instances where discriminatory effort is continued in spite of distraction, fatigue, and stress (47).

For a long time psychologists were unable to explain why some human subjects could endure long periods of work or sleep loss and distraction without obvious impairment in overt performance. As soon as records were made of the general amount of supporting neuromuscular tension the "mystery" disappeared. In one of the early studies (110), it was found that subjects who performed well or even better under disturbing (as against quiet) work conditions did so by virtue of compensatory increments in muscular tension. In two later studies on distraction (33, 120) muscular activity was initially increased, but dropped off as the subjects became habituated to the distraction. A study of performance following sleep loss (47) also showed the compensatory effects of increased muscular tension. In general, the greater the sleep loss, the greater the degree of tension mobilized to support the ensuing standard test performance. These compensatory tension increments varied more directly with the work demands than did the

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output scores, a fact which might be interpreted as indicating that the subjects were attempting to maintain performance constancies. During an hour and a half of continuous work (75), tension increments were progressive in compensation for the ever-increasing demands of relative fatigue. This presents the reverse picture of a learning series, since with time the tension pattern spreads or irradiates to more and more muscle groups.

In these studies of the compensatory energetics necessary to meet fatigue and sleep-loss effects, the organism is, of course, drawing heavily on energy reserves and so is accumulating a greater "debt." These studies have not attacked the long term aftereffects of increased compensatory effort. Presumptively, there will be a tendency for the reactivity to drop off and only gradually to recover its original level as the organism rebuilds the reserve by conserving energy and responding to a more limited stimulus field.

The fact that tension increments under distraction tend to drop off with protracted exposure to a stimulus suggests that a more economical distribution of energies has occurred in the process of becoming "adapted." According to a study (55) which recorded concurrent changes in four muscle groups during adaptation to noise distraction, such reductions in the general level of compensatory energy mobilization appear to be due to a shift in a tension pattern that functions more economically. The work problem used in this study was serial addition, and during quiet conditions tension tended to be concentrated in muscles of the arm that wrote down the sums. The first effect of distraction was to increase tension in other and "unrelated" limbs, as well as to cause a rise in the general metabolism; after the second day of work under distraction, however, the tensions

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of the unrelated muscles decreased progressively. The tension of the reacting arm remained a little higher under distraction than under quiet conditions, but apparently was not enough to cause a recordable increase in total energy mobilization or metabolism. It would seem that this work is in line with results on differential tension in learning; that is, the supporting bodily processes at first outbalance the distractional effect by extensive and intensive increments in tension. After a time, a less metabolically costly pattern of tension is established. Thus is accomplished an economy of effort, and work output during the entire readjustive process remains fairly constant.

The Limits of Discriminative Adjustment. Study of compensatory effort indicates that the organismic energy system can be pushed too far in its drive to maintain discriminatory control over homeostatic behavior. Energy mobilization will support increasing effective adjustment only up to a certain point (optimal reaction range). When discriminatory processes are forced beyond this point, the whole mechanism of higher nervous control breaks down. Pavlov, and many after him, has shown that the way to experimental neurosis in animals is to force discrimination beyond inherent capacity. When inability to solve a problem is coupled with inability to escape from it discriminative processes fail and the animal reverts to the lower level of nondiscriminatory emotional behavior; it snarls or cringes at all objects, or withdraws from the effects of external stimulation in a sort of narcoleptic sleep.

In human subjects, the presence of socially accepted standards of discriminatory performance puts an even greater load on the adjustive system. Because of individual differences in discriminatory capacity and directive control, some people will have great difficulty in attaining work

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standards that meet with general approval. Usually these standards are set somewhere within the efficient working limits of the average human machine. Because of social sanction, great will be the striving to stay with these average standards. Men who can attain the average standard of discriminative adjustment while working below their most potentially efficient level have unused energies that tend to get them into trouble with society. Even more serious are the cases of men who must work beyond their own most efficient level and still do not attain performance equivalent to that which society approves. Unless remedial procedures (including lowered aspiration standards or work demands) are instituted, these men are headed for nervous disorder and discriminatory collapse. Especial attention should be given to individuals who are making the grade, discriminatively speaking, only at considerable cost to themselves. The world is full of people who attain high performance scores, solve stimulus problems quickly, and outwardly appear as masters of efficiency. How many of them carry harmful residuals from overcompensations of effort not even their physicians may suspect until there is concrete evidence of ulcer, high blood pressure, and other psychosomatic disorders.

It is a grave mistake to place reliance on the outward manifestations of highly discriminative adjustment in gauging the homeostatic efficiency. Some of our best adjusted men in terms of their outward front are the most maladjusted internally. Contrawise, some of the most nervous acting, maladjusted appearing men are the most physiologically calm and relaxed on the inside. Neuroticism, nervousness, and maladjustment are something far more fundamental than extravagant and fidgety overt behavior; they are unreleased and self-perpetuating internal nervous

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excitement. Until objective psychology forsakes its preoccupation with the overt behavior criteria of discriminatory adjustment and includes covert measures of the internal consequences of such responses, it will remain out of contact with the major dynamic problems of personality formation and total behavior in health and disease.

Personality Differentiation

The Measurement of Personality. The term personality has been used by psychologists to mean either the sum total of a number of isolable "traits" or the particular integration or the "pattern" of responses that determines the uniqueness of the individual. Because of its dynamic implications, the second type of definition ¹ is today the preferred one.

The newer emphasis in personality study has shifted from the attempt to isolate traits to an investigation of patterned wholes. If there is any discussion of trait factors, it is their particular arrangement of grouping that is said to distinguish one individual from another and not the summation of measured amounts. Frequently, it is also held that the uniqueness of the individual personality pattern renders futile any analysis into elements which, when isolated and measured, lose their meaning. Because this latter

¹ Space does not permit detailed analysis of definitions of personality. The common-sense notion receives sanction in May's "social stimulus value," which hardly distinguishes a person from a cocktail. Pattern definitions of deeper psychological insight include Lewin's "dynamic unity of functional systems," Frank's "dynamic process of organizing experience," Murray's "personality pattern," and Allport's "dynamic organization within the individual of those psychophysical systems which determine his unique adjustment to his environment." For a discussion of these convergent trends, see the report of S. Rosensweig, *Psychol. Rev.*, 51, 248-275, 1944. On the relation of isolating and pattern approaches to personality, cf. R. B. Cattell, *Description and Measurement of Personality*, World Book, 1946.

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view is at variance with canons of scientific procedure, it should be examined very critically. The two aspects of personality measurement, factors and their patterning, are reconcilable, as Cattell² has already shown. What follows herein may be regarded as a further attempt to relate the well-intentioned interests of pattern advocates to the basic problem of what is being patterned in personality structure.

The current vogue for qualitative appraisals³ of the total personality pattern is due largely to the failure of the existing quantitative methods to attain significance. For example, most personality inventories which once seemed such promising extensions of "intelligence" testing have now run themselves into the ground. Statements to the effect that "improvement in personality measurement takes place primarily through the application of control and of quantitative analysis to the classical (questionnaire) techniques" have proved to be little more than a pious hope. Paper-and-pencil tests which question others or the individual himself have been improved to a fine point; but no amount of involved statistical treatment can increase the value of questionable data. A major difficulty in this

² *Op. cit.*

³ Qualitative and quantitative methods do not stand as things apart; rather they are ranged on a continuum. The first approach to any problem is relatively crude and qualitative. With further work, methods become more refined and quantitative. If, however, a given approach becomes refined without yielding a satisfactory solution, it then becomes necessary to develop a new approach to the problem, and this will look very qualitative when compared with the refined but erroneous procedure it would replace. Today's pattern approach to personality looks very "qualitative" when compared with the questionnaire tests. It may, however, become more "quantitative" with time. We should recall that the intelligence tests of Binet, which now have great "quantitative" respectability were once regarded as very uncontrolled and qualitative when compared with the chronoscope measurements that set the pattern for psychological measurement in the early twentieth century.

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approach is the considerable confusion, as with Cooley's looking glass, between the self one should see and the self as he would like to be seen. Whenever such tests are given under conditions which suggest their social value (and few tests are constructed so as to conceal effectively the trait under examination), the answers fail to correlate with either clinical observation or objective behavior tests in which the important variables are unknown to the subject.⁴ Likewise, even highly trained raters and those who know the person very well may turn in quite different estimates of his personality, because of failure to see him operate in the same bounded behavior situation.

Inability to predict total behavior from isolating trait tests is all grist for the mill of "pattern" advocates who somehow seem to feel that this failure also absolves them from making precise measurements. Verbal criticism of the isolating technique wins no battles. It is amusing to point out that when only the bricks that come out of a house are counted, a person interested in reconstructing the whole can form with them either an Arabian mosque or a roadside stand. But in the absence of more efficient methods for handling the classification of men, personnel experts must continue to compute isolable "trait" scores, and thus inadvertently set the total individual down as a scattered assemblage of traits or abilities represented on a Hollereth punch card.

There is a middle ground somewhere, and this we must find before real progress in personality assay is made. As-

⁴ Confirmatory evidence is shown in I. A. Fosberg's study (*Rorsch. Res. Exch.* 5, 72-84, 1941) on the influence of suggestion on questionnaire tests, and also in the work of G. L. Freeman and E. T. Katzoff (73). J. P. Guilford (*Amer. Psychol.*, 2, 8, 1948), however, has pointed out that in air-force selection some inventory factors "may be valid in spite of the bias the examinee is able to and may introduce."

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suming that valid personality "traits" or parameters do exist, their isolation and objective measurement could then be followed by a study of their quantitative relationships in the make-up of the so-called "total personality pattern." Since such parameters would exist in different amounts in each individual, an infinite variety of total dynamical structures would be possible. The obvious approach, which should satisfy both trait isolaters and pattern advocates, is to *expose a sample population to a wide variety of controlled stimulus displacements, measure the most significant aspects of response, give the data a refined statistical treatment to determine the major parameters of differentiation, and then study their interactions.*

The Study of Personality Patterns. There is no necessity to review here the results of isolating techniques which separated intellectual and temperamental "traits," gave us the "primary mental abilities," and developed a scale of extroversion-introversion. We shall begin, instead, with a consideration of the newer "projective methods," since these are the first to attack directly the problems of the total personality pattern. The most highly developed of these methods is the Rorschach technique, in which the subject is given a series of standardized ink blots. Upon this relatively unstructured medium of expression, the subject is said to "project" his total personality pattern, and the verbal responses made to various aspects of the stimulus cards are recorded and analyzed. A "psychogram" showing interactions of such alleged factors as "form perception," "organizing energy," and "affective drive" provides the basis for diagnosis and intuitive prediction. For example, the superior, well-balanced adult is characterized by "high organizing energy, coupled with accurate form perception and outgoing affect."

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It is obvious that such projective approaches to personality assay give major emphasis to the interreaction of ill-defined factors quite without validation in terms of more objective criteria of response. As a result, highly controversial claims have arisen.⁵ Correlations between clinical types and Rorschach patterns have been reported, but the Rorschach results in the Armed Forces were almost completely negative. Not only did Rorschach patterns fail to differentiate between hospitalized psychoneurotics and normal men but intuitive predictions of trained Rorschach examiners gave no significant indications of validity against the pass-fail criterion in pilot selection. Somewhat similar results have been reported for other projective approaches to personality pattern, including the Thematic Apperception Test (TAT) of Murray. Significant predictions are sometimes made, but even as this occurs, the scores are not cleared of a large subjective contribution on the part of the examiner. The very wealth of responses permitted was a hindrance to their adequate definition and measurement. Intuitive pattern predictions derived from different types of tests showed zero relationships in many instances. Only where the stimulus was more limited and the range response more standardized, as in quasi-standardized stress situations, was there significant correlation between objective scores of performance and subjective estimates of personality structure.

The foregoing paragraph suggests that a better under-

⁵ For a review of projective methods, including the Rorschach, cf. H. Sargent, *Psychol. Bull.*, 42, 257-294, 1945. J. F. Brown (*Psychoanal. Quart.*, 6, 227-237, 1937) discusses the relation of psychoanalysis and Lewin's topological descriptions to the global approach to personality structure. The experience of various branches of the Armed Forces with pattern approaches to personality is not yet available to general circulation. For a report based on such data, cf. J. P. Guilford (*loc. cit.*).

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standing of personality patterns may come both from limiting the stimulus situation and from refining the measures of response. While a pistol shot does not offer as great a range of displacement value as the ink blot and while response will be more stereotyped in the situation, this state of affairs has its advantages. If range of stimulation and range of reaction are more limited by the pistol shot displacement, the "projected" expression of individualized response pattern here receives its acid test. Correlation of fully quantified responses obtained in different displacement tests might then reveal the fundamental parameters whose patterned interactions are being grasped vaguely by the less rigid experimentation of projective techniques.

Our own approach to the problem of personality pattern has involved the study of physiological reaction dynamics in controlled laboratory situations. It has been our hypothesis that the major parameters whose interaction determines the personality pattern are discoverable through measurement of physiological reactions to common disequilibrating stimuli such as the pistol shot and in frustration tests.

The Role of Frustration. The way in which individuals of specific biological constitution meet displacements in their potential field of stimulation seems to have a great deal to do with the formation of personality patterns. For discussion purposes, frustration is here said to occur whenever the individual meets an obstruction in the route to the satisfaction of some vital need. Frustration of relatively unlearned homeostatic acts such as fight or flight is essential to the development of a socially mature and well-adjusted personality. Frustrations demanding new solutions help mold discriminative capacity and intelligence. Without frustration we should have little personality development and

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little response integration. As the individual ages, his reactions to frustration tend to follow the grooves of habit and thereby to mark what is unique about him.

There are, of course, optimal conditions of frustration for the development of personality structure. Insufficient frustration spoils a child, so that he is later unable to withstand the placing of any obstacle in his path. Excessive frustration, on the other hand, creates low areas of tolerance which carry on in life as "complexes." Persistent "nonadjustive" responses may become deeply set under continued frustration, but success experience in a field the individual accepts as important will do much to compensate for the disruptive effects of many failure experiences in other fields. A pattern of action emerges gradually which exhibits considerable consistency despite differences in situational setting. It is these persistent bodily trends molded by reaction to frustration that are presumably tapped by the experimental conflict situation.

The use of experimentally induced frustration tests in personality study appears to simplify the problem and subject the field to standardized procedures. Like the displacing ink blot stimuli of projective technique, they are a method for exposing the deeper layers of personality structure to examination. In frustrating situations, basic homeostatic defense tendencies, usually concealed by more superficial response adjustments, are often revealed in startling clarity. The emergent reaction tendencies have most frequently been described as primitive and regressive.⁶ They

⁶ As Lewin (*Psychoanalysis and Topological Psychology*, Bull., Men. Clin., 1937) has already pointed out, behavior under frustration is not necessarily retrogressive, in the Freudian sense of a return to specific infantile modes of expression. When behavior is called infantile we mean only that it is not adult in the sense of being highly discriminative and socially controlled. The term regression indicates a shift to a lower and

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take forms of expression varying from meek submission and self-punishment to active dominance and aggression in the situation. When the stress stimulus is a standardized one,⁷ the degree and type of regressive behavior that emerges is subject to measurement. The effectiveness of various reaction tendencies can be graded and the physiological variables that underlie the total patterned adjustment are open for study. The further question of how "typical" a given reaction is for different frustrating situations can also be answered, and thus the consistency of the individual's reaction tendencies is revealed.

Stress Testing. Most attempts to study personality pattern through analysis of reactions to standardized stress

more basic level of personality integration, and there is little reason to examine how specifically the regressive behavior corresponds to earlier behaviors of individual history, except as one wishes to change the pattern. Studies by Lewin's students on social climates and anger show that both the situation and the person contribute to the emergence of the regressive behavior. For the tremendous range of overt behavioral outcomes produced by experimental frustrations, see the descriptions of Dollard *et al.* (*Frustration and Aggression*, Yale Univ. Press, 1939). One man reacted to experimental deprivation of sleep by drawing dismembered and disemboweled bodies which he referred to as "psychologists." Another subject gave an outward unpression of meek submission, but was ill with an intestinal disturbance the next day.

⁷ It must be appreciated that the physical value of a stimulus is a very incomplete measure of its value for the individual. A "standardized displacement" is standardized with respect to its physical aspects only. For this reason those startle stimuli which have the least difference in social value for different individuals will be a favored choice in experimental programs. Further standardization of the situation can come only by equating many displacements from individual to individual. The finding that, attitude-wise, an electric shock can be "all things to all men" (S. S. Tomkins, *J. Psychol.*, 15, 285-297, 1943) is not a serious drawback, providing the experiment includes a measure of the affect value of the stimulus. It is for this reason that we have used skin conductance measures of energy mobilization in experimental frustration tests. Cf. also (106) and (86).

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conditions have been at the overt behavioral level. Many of these explorations have been of such limited scope as to be of questionable value in revealing basic aspects of personality pattern. We shall, therefore, consider only those approaches which carry the individual through several stress tests and which attempt to provide an integrated result. The first of these was developed by German military psychologists for the selection of army officers and other specialized personnel. The second includes certain of the methods used in a long-term clinical study of the personality patterns of college students. The third is a *stress interview* based upon the principles of more limited laboratory displacement studies and used in connection with the selection of police officers. Each of these approaches will be discussed in turn.

The basic procedure of the German officer selection methods⁸ is the clinical observation of the candidate while he is working under pressure and environmental stress. Trained raters conduct these behavior tests, and credit is given to testees who exhibit the qualities of bold intelligent action in the face of confusion, who persist in their attempts to achieve assigned objectives, and who exercise a favorable dominance over the men who work with them in certain test situations. The fact that these lifelike (non-laboratory) tests last two full days is itself enough to wear down a man who cares little about succeeding in the competition of life. The polite suavity is peeled off many a candidate. The impractical idealist sees his own inadequacy. Overambitious candidates are shown that their

⁸ Cf. H. Ansbacher, *Psychol. Bull.*, **38**, 370-392, 1941; H. A. Murray, *Amer. J. Psychiat.*, 1944. For the relation of projective (Rorschach ink blot) technique to stress testing, cf. M. R. Harrower and R. R. Grinker, "The stress tolerance test," *Psychosoma. Med.*, **8**, 3-15, 1946.

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aspirations far outrun their achievements. Men of muscle find out that "a sound mind in a sound body" does not mean that they can neglect their intellects. In general, the pretensions and the acquired social veneers are stripped off and the predominant or basic parameters of personality structure are revealed.⁹ Ultimate selection or rejection rests upon the examiner's judgments of the personality as a whole. One man is selected because he can think independently, is not easily rattled, and seems able to apply his energies to a problem without thought of self. Another man is rejected because he makes poor use of his intellectual powers under stress, fluctuates in emotional stability, frequently changes his opinions to conform with those expressed by the examiners—"a timid mouse who will do anything for food." It would be difficult to say just how or when these total judgments are reached in the tests. The clinical character of the data makes precise and objective evaluation impossible; but that these estimates of personality structure have some predictive accuracy is indicated by their similarity to follow-up descriptions made two years later.

Methods used by Murray¹⁰ in his studies of the personalities of college students also employ clinical ratings. These are made upon the basis of behavior observed in controlled lifelike situations of stress and neutrality. In the final synthesis of behavior ratings, those made by the more experienced observers are weighted. Murray's primary purpose is an understanding of total pattern differences in personality structure rather than of basic variables, and his

⁹ This particular device has frequently been employed in the theater to dramatize the difference between the superficial and basic aspects of personality structure. Cf. *Strange Interlude*, *Dear Brutus*, *Cry Havoc*, and *Journey's End*.

¹⁰ *Op. cit.*

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present descriptive classifications have little statistical validity. Our chief interest in this work is its recognition of the experimental frustration test as a method for the study of personality differences.

The *stress interview* method (76) was designed to unite the clinical approaches (which emphasize intuitive judgments of total patterns expressed in extended episodes) and the laboratory approaches (which emphasize isolable test scores in situations more limited and controlled on the side of both stimulus and response). The essentials of this type of frustration test are the exhibition of typical and basic behavior patterns through the manipulation of the individual in bounded situations of stress and nonstress, together with quantitatively scaled ratings of the observed behavior and related objective measures of energy mobilization and discharge. The individual is first placed in nonstress situations (questioning and performance tests) favorable to the exhibition of high-order discrimination reactions; then these situations are changed so as to be unfavorable to the continued operation of such reactions; finally the external situation is returned to the former nonstress condition so as to observe the subject's recovery. Here a limited episode affords opportunity to study both the gross clinical aspects of neuromuscular homeostasis and the finer physiological aspects of energy mobilization and discharge. Marked individual differences occur in such quantifiable aspects of response as arousal, discharge, and recovery. Sex differences (102) are not noted for R.Q., but females are more reactive to stress, more relaxed after reaction, and less adaptive to repetition.

Although very few of the personality differences observed in other frustration studies have yet received precise quantification, certain rater-judgments made in the *stress*

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interview have been found to be correlated with physiological measures of neuromuscular homeostasis (76). It appears, for example, that the significant behavior trend toward aggression or submission under stress is related to changes in energy mobilization from stress to nonstress conditions. Predominantly active aggression or blocked submissive behavior (the extremes of a scale) tends to appear in persons who are highly aroused by the stress tests. These same persons also exhibit under stress the most serious interference in objectively recorded performance scores (discriminative behavior). Skin conductance R.Q. is somewhat lower for individuals rated submissive than for those on the aggressive side of the continuum. This is perhaps due to the fact that submissive behavior is usually an inadequate discharge of aroused excitation, whereas moderately aggressive behavior discharges more aroused excitation. The general suggestion conveyed by such data is that at least one important aspect of total behavior (aggression-submission) is linked with underdischarge and overdischarge of aroused bodily energies. However, this is not meant to imply that the stress test, of itself, will solve the problem of unraveling all the major parameters of personality structure—much less uncover the underlying basic physiological variables.¹¹

¹¹ Some of the above results were obtained after publication of the original *stress interview* report (76). The correlation between the submissive-aggressive rating continuum and the skin conductance R.Q. was $-.33$ for twenty police officers. The correlation for twenty-four college students observed in an analogous situation was $-.21$. In order to test fully the hypothesis that submissive behavior is an inadequate discharge of aroused bodily energies, the affective stimulus value (measured by energy mobilization) should be held constant for the individuals included in the experimental sample. The fact that this condition was not met for the groups surveyed gives even the low correlations considerable interpretative significance. Cf. (63) for suggestions toward a standardized stress test.

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The *stress interview* and related frustration tests are regarded first and foremost as controlled approaches to the estimation of individual differences in neuromuscular homeostasis. More drastically than the ink blot stimuli of projective technique, more acutely than the extended behavior episodes of Murray and the German officer selection methods, they face the organism with a situation which exposes certain basic factors in personality pattern. Its use is recommended in any test program that proposes to factor the personality complex.

The Problem of Psychophysiological Assay. We have come, now, to a basic orientation in personality study—the physiological factors which presumably underlie the behavioral trends revealed by projective methods, intelligence tests, personality inventories, and stress tests. Every type of personality diagnosis—from psychoanalysis to trait scores—has always implied physiological variables. Yet, somehow, the correlation between psychology and physiology fails to materialize.

It is an open secret that the psychophysiological approach to personality owes its current unpopularity to the negative results of many early studies. Correlation of psychological inventory scores with some set of anatomical or physiological variables would be a welcome simplification of the problem, and all manner of suggestions have been tried. Body build and static physiological measures have, however, been found wanting,¹² and physiological measures of dynamic change have received only limited trial.

¹² The problem of constitutional factors in personality is not solved by use of any available anthropometric techniques, though three components of structural variation (endomorph, mesomorph, and ectomorph) have recently been reported to correlate with temperament traits allegedly associated with viscerotonia, somatotonia, and cerebrotonia (W. H. Sheldon, *Constitutional Factors in Personality and Behavior Disorder*, Ronald,

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Most studies of individual differences which have used physiological measures make the fundamental error of not carrying the observation over a long enough period to isolate the behavior trends which are symptomatic and typical of the individual. For example, two individuals with the same level of basal metabolism may be fundamentally different as regards the mechanism employed in the maintenance of that basal state. Again, it is possible for a single observation of basal condition to fall within the normal range, whereas a study of its changes from day to day may show considerable variability. This is perhaps one of the most significant diagnostic signs of unstable homeostasis. Cardiologists commonly report that a single day's record may show a normal cardiogram, but that when the survey is integrated over several sessions, the range of variation may be found beyond normal and so provide an early diagnosis of disfunction.

In addition to lack of appropriate indices of variability, erroneous choice and interpretation of data have hampered physiological assay of personality structure. Lack of forethought in the choice of measures, paucity of serial recording, and the great predominance given to absolute static measures (such as BMR) over those of relative change are largely responsible for the mass of negative evidence that meets one on all sides. Surveys of the literature show that confusion reigns whenever a single sample of physiological activity is taken in conjunction with clinical diagnosis or self-ratings of personality. Even those time-consuming and expensive "dragnet" procedures which use all available physiological measures on the same population will accomplish next to nothing unless the experiment is designed to develop the data in a dynamic rather than a static frame of reference. Only recently have we begun to see the importance of such derived measures of physiological change as the "per cent skin conductance increment," the "motor discharge ratio," and the "physiological recovery quotient." These are measures of the same type as the "hyper-glycemic index" of limited organ homeostasis. Their further development in connection with experimental frustration tests should do much to bridge the gap between total bodily function

1944). Limited static tests of basal metabolism pH of the blood, etc., have likewise shown little evidence of correlation with clinically differentiated types. For a review of this work cf G. L. Freeman, *Physiological Psychology*, Van Nostrand, 1948.

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as understood by the physiologist and personality as understood by the psychologist.

In rethinking the problem of psychophysiological assay, it is well to recall that *the most important feature of the organism is its tendency to maintain a dynamic equilibrium*. Only in some such perspective can available physiological measures be utilized effectively in the study of individual differences. This is borne out in studies of the equilibrium of the blood under various conditions. It was found (104) that the most significant differentiating factor between individuals who had spent a wakeful night and the control group who had slept was that in wakeful individuals the changes in blood chemistry produced by muscular work took longest to return to normal after cessation of work. This suggests that just as the lack of sleep alters primarily not the absolute state of equilibrium of the blood, but only the stability of that state, so residue from emotionally displacing situations are likely to affect the stability of physiological patterning before they cause fundamental changes in the activity level of any one element in the system. Return to dynamic equilibrium may be accomplished by shifts among the several part-mechanisms involved in total neuromuscular homeostasis.

Finally, while displacement ordinarily does change quantitative relationships within the body tissues, no particular change will always be present in all the individuals included in the population surveyed. Change in a given quantitative element may not be shown, but other processes not under observation and measurement may change in the maintenance of the observed constancy. This indicates the need for extreme care in the selection of bodily indices of change, and helps to explain the fact that the most satisfactory differentia of individuals are usually obtained by

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simultaneous study of several physiological reaction systems rather than of any one alone. The dynamic changes in these several measures of energy mobilization and discharge together with the derived measures of interrelationship (such as R.Q. and F.B. ratio) are the essence of a productive physiological attack on individual differences in personality.¹³

Used in connection with experiments that expose the individual to a variety of displacements, from simple sensory stimuli to stress questions, they should provide the data needed to answer the following question: Are there any basic parameters in neuromuscular homeostasis along which individuals distribute themselves and whose interactions differentiate one personality pattern from another?

Nonfactorial Studies of Physiological Differentiation. Most physiological studies of individual differences have been inadequately treated from the statistical standpoint and lack the involved manipulation of data that have been found useful in many psychological studies. Furthermore, most physiological recording methods confine research to small samples not open to the treatment of conventional group statistics. Only recently has the development of small sample theory and factorial analysis been applied to physiological measurements. The studies that preceded the development of such treatments have value, however, and will now be reviewed.

In one of the first attempts (26) to study individual differences in neuromuscular homeostasis, normal subjects

¹³ In this connection, it appears that Luria's work (105) on simultaneous recording of two or more discharge levels in experimentally induced conflict might have attained even greater significance had the interrelations of the measures been treated quantitatively.

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were given a series of electric shocks designed to reveal such quantifiable aspects of reaction as anticipation, excitability, recovery, adaptation, conditioning, and inhibition. Response curves were obtained for blood pressure, respiration, galvanic skin resistance, and movements of the stimulated area. In addition, questionnaires designed to reveal variations in "neuroticism" and "emotional instability" were administered. No high correlations were found between physiological and psychological tests, though subjects whose rate of physiological recovery from shock stimulation was most rapid tended to be rated as emotionally stable.

In a later research (58) normal adult males were subjected to several varieties of displacement, including voluntary inhibition of micturition and the withstanding of protracted electric shock. Measures of physiological displacement and recovery were obtained from records of palmar skin conductance, blood pressure changes, etc. These physiological recovery (R.Q.) changes were intercorrelated with each other and for different types of displacing situations. Considerable correspondence was noted between these recovery changes and the individual's ranking in other tests of nervous stability (such as length of time micturition was voluntarily inhibited) and responses made on neurotic inventories. To some extent the relative ranking of R.Q. scores on different displacement tests appeared to be influenced by ability to re-equilibrate to one type of displacement better than to others. Furthermore, subjects undoubtedly exerted different degrees of reinforcement in reaching the same measure of overt behavior; for example, the time criteria in the micturition tests. This has been one of the great difficulties in using overt behavior (as in the

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animal studies of experimental neurosis) as an index of nervous breakdown.

Subjects in the next R.Q. study (61) were trained to make right- or left-hand reactions in signaling the discrimination of "lighter" or "darker" in a pair of near-threshold stimuli. Shocks were given for wrong responses and for failure to respond within a standard time. As with Pavlov's neurotic dog, the experimental series began with "easy" discrimination of widely separated stimulus-pairs, and the difference was then narrowed down until both numbers were alike. To test for the effect of frustration, as soon as the subject made three consecutive failure reactions, without his knowledge he was again given the original "easy" discrimination pairs. The differential between first and second reactions to the "easy" discriminations became an overt behavior index of homeostatic breakdown. Those who showed breakdown on "easy" discriminations following work on "hard" problems also tended to have low skin conductance R.Q.'s. The correlation, however, was not sufficiently high to make possible individual prediction from overt to covert measures. Another overt measure (number of trials successfully passed before the three failure reactions occurred) correlated even less positively with the covert R.Q. measures. But the relationship appeared more precisely when studied at a more complicated level of performance difficulty (69). Such data suggest that individuals who cannot long withstand experimental frustrations and whose overt behavior is most disturbed thereby also tend to recover physiological equilibrium slowly. The stable system, on the other hand, is more resilient, reacts adequately but not excessively to frustration, maintains available energy for additional loads imposed, and shows

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little residual tension following overt reaction and removal of the stimulus. Not known, of course, are the number of axes of differentiation involved in these standardization frustration tests, or their precise relationship to the total personality pattern. The pertinence of physiological recording to personality study is, however, revealed by such work.

Factor Analyses in Physiological Differentiation. Every psychophysiologicalist will recognize that the ultimate test of the axes of personality differentiation is an involved statistical one. The organism must be exposed to a variety of test situations and the intercorrelations of a variety of physiological measures must be obtained. Next comes the "factoring" of this complex and the positing of the least number of axes needed to account for the major variance. It is significant that until very recently little or no attempt was made to study the physiological reactions of a sample population exposed to a variety of standard test situations. In such studies as have been made, the number of subjects has been small and most of the physiological measures have been static, rather than dynamic, in character. Consequently, the following results must be regarded as exploratory.

The first factorial study of physiological variables (142) was carried out on only six subjects, and included a battery of questionnaire personality tests as well as many static measures of physiological reactivity (B.M.R., resting skin resistance level, and blood pressure). This study yielded evidence of three different factors: (1) a "metabolic" factor, (2) a "muscular tension" factor, and (3) an "emotional lability" factor. Few questionnaire tests gave any evidence of correlation with the physiological measures, and the presence of a cretin in the group of six subjects may have

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accounted for the high loadings of the first (metabolic) factor.

Subsequently, the same investigator, using much larger samples (140, 141), determined the interrelationships between such variables as reclining and standing changes in pulse and palmar skin conductance, the latency and persistence of red *dermographia*, salivary output, and percentage of solids, changes in respiration and heart rate, basal metabolism, and residual muscular tension after instructions to relax. A factorial analysis of the results indicated two significant common factors. These were called "autonomic balance," or condition of the autonomic nervous system, and "muscular tension," or the relaxability of the skeletal musculature. The variables correlating with each factor were then used in deriving, by means of the technique of multiple correlation, a regression equation for estimating these factors for individual subjects.

Such work is significant, but cannot be directly related to homeostatic factors operating in more complex behavioral adjustment. It will be noted that all measures were taken under conditions of rest or minor physiological disturbance and that no records were taken in frustrating situations, such as was recommended earlier in this chapter. The picture is confined to factors operative in the maintenance of the basal activities of rest. If these same factors are to apply to differences in reaction at more complicated levels of stimulation and stress, we must look to the work of other investigators.

Only two factorial studies are available in which physiological reactions to a variety of experimentally induced displacements have been recorded. In one the subjects were thirty-eight school children, differentiated by behavior ratings into "well-adjusted" and "maladjusted" groups. In the

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other, the subjects were twenty-four male college students.

The study of homeostatic reactions in children (99) showed twenty-seven variables (from an original total of fifty-two measures) which differentiated the maladjusted and the well-adjusted groups; of these "galvanic (skin resistance) recovery" following stimulation proved to be a highly significant index. A factorial analysis of the data was performed for the eighteen cases in the "well-adjusted" group and yielded three factors. The first factor was heavily loaded with a rating of "emotional stability," "per cent time alpha" of the electroencephalogram, and "basal muscular tension"; it was labeled an "emotionality" factor. The second factor had three significant loadings, all concerned with the increment of physiological activity during stimulation; for rather obscure reasons, this was labeled by the author of the study as a "central" factor. The third factor contained no significant loadings.

The study of homeostatic reactions in college students (72) recorded skin conductance and overt reaction changes (restless movement, voice level, etc.) before, during, and after four types of stimulus displacement (unexpected pistol shot, motor conflict test, verbal association conflicts, and pitch discrimination under distraction). In addition there were clinical ratings of "emotional balance" and self-ratings of "neuroticism," "drive," "discharge control," and "response variability."

Thirty variables were subjected to a factorial analysis. This analysis resulted in three factors. The first was heavily loaded with conductance R.Q.'s in the different types of experimental frustration, with "basal" restless movement, and with clinical ratings of emotional balance; it was labeled by the authors as a "discharge control" factor, related to the central nervous control over the discharge of aroused

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excitation. The second factor was heavily loaded with measures of stimulus-produced increments in physiological activity and was labeled an "arousal" factor. The third factor was heavily loaded with questionnaire trait scores and was labeled by the authors as "self-rated neuroticism."

The fact that self-estimates of "arousal," "discharge control," etc., failed to correspond with objective behavioral indices of these factors suggests that the subjects answered the personality questionnaires in terms of their knowledge of acceptable behavior rather than in terms of their more basic inclinations. This defect would be especially pronounced with psychologically sophisticated subjects such as were used in the study under examination. Only those "variability" items—the intent of which was concealed in the questionnaire tests—gave any evidence of correlation between a self-estimated trait and a related physiological condition exhibited in an actual behavior situation. This suggests that if more measures had been taken of the subject's tendency to change his written response to equivalent forms of the same question, a significant "variability" factor might have resulted from this study.

It is worth special comment that two studies, independently designed and conducted from entirely different angles, should reveal compatible results with regard to the physiological variables involved in response differentiation. The cognate discovery of such factors as bodily arousal and the control of its overt expression transcends simple chance. It also appears that the factorial studies based upon physiological variations in more static test situations are likewise related to these same aspects of response. For purposes of comparison, therefore, we have listed all the factorial studies of physiological reactions in man, together with an analysis of their major axes of differentiation. It

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should be noted that the existence of a third factor is most uncertain.

Physiological Factors in Personality Differentiation *

<i>Study by</i>	<i>Factor 1</i>	<i>Factor 2</i>	<i>Factor 3</i>
Wenger (142)	Emotional Lability	Muscular Tension	Metabolic (?)
Wenger (143)	Autonomic Balance	Muscular Tension	
Jost (99)	Emotional- ity	Central	?
Freeman and Katz- off (72)	Arousal	Discharge Control	Variability (?)

*Although studies that do not employ physiological measures have been excluded from this table, it might be that the Rorschach factors of "affective drive" and "organizing energy" are expressions of the underlying physiological variables mentioned above. It is regretted that appropriate correlational studies have not as yet been made.

Bodily Basis of the Arousal Factor. If we assume an *arousal* factor as a fundamental axis in personality differentiation, our next problem concerns its constitutional basis. Though this is not well understood, there is recent positive evidence (143) for a linkage with the autonomic (or interofective) nervous system. Following an early suggestion that this system tends to function as a unit with the average or "normal" individual resting somewhere between the extremes of vogotonia and sympatheticotonia, it has been found possible to range a sample population on a quantitative continuum of "autonomic balance." The measurement of "autonomic balance" is relatively stable and therefore highly reliable (143). It is presumed that persons whose resting bodily condition is habitually "balanced" on the sym-

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pathetic side are given to excess excitability, sensitiveness, and energy mobilization. Nothing is known as to the influence of environmental conditioning on this factor; but important as amount of stimulation is to arousal, something more "innate" and constitutional is probably involved. The intimate connection of autonomic function and endocrine activity is generally recognized. A promising suggestion, therefore, is that glandular differences may produce variation in amounts of available energy mobilization which the organism uses to meet disequilibrium.

Pathology has shown many curious distortions in personality structures which accompany the malfunctioning of thyroid, pituitary, and sex glands. These glands have considerable to do with making stored bodily energies available for homeostatic adjustment. If the quantity of hormones produced is related to the size of the glands, great differences in the amount of stimulation derived therefrom would undoubtedly exist among individuals. Enormous variability has been found in the weights of the endocrine organs, and while the weight of the brain, heart, and visceral organs is proportional to the total body weight, the endocrines show no such constant relation. When a small thyroid is forced to "spark" a group of larger organs, this will obviously not produce the same behavior effects as when a large thyroid is balanced against a similar organ relationship.

Hall and other experimenters have indicated a correlation between the size of adrenal, thyroid, and pituitary glands in emotional and nonemotional strains of rats. So complex are the problems of glandular balance and interrelation, however, that at present few definitive statements can be made regarding the glandular-autonomic basis for the drive-arousal factor in personality structure. It is yet

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purely speculative to suggest that the arousal factors found in studies of neuromuscular homeostasis have an endocrine basis, with some individuals constitutionally excitable and others phlegmatic. It does appear that individuals differ in amount of energy available for meeting work demands and frustration. Though the various bodily tissues operate together in the complex, the endocrines are primarily "releasers" of stored energies. The fact that high metabolism has been reported to correlate with high tested intelligence and with highly social indices of activity (90) would certainly indicate that hyperactive glands contribute to those energy mobilizations which support the homeostatic adjustments of total behavior. Further than this we cannot go at the present time.

Bodily Basis of the Discharge Control Factor. Throughout our discussions of neuromuscular homeostasis the problems related to the *control* and *expression* of aroused bodily energies have bulked very large. Factorial analysis of homeostatic reaction to various displacements has indicated that physiological recovery depends upon the control exerted over the overt expression of aroused excitation. No cues were here provided as to constitutional bases, though it was surmised that the "control" factor is more subject to environmental influence and training than is the "arousal" factor.

The experimental literature on the indices of neuromuscular control is not large. Apparently, an individual may inhibit the outward discharge of aroused energies or express them so fully that the response re-excites. Both of these extreme conditions suggest residual muscular tension, and this measure has, in fact, proved to be an indirect means of estimating discharge control.

Though William James proposed many years ago an in-

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timate relationship between the explosive type of personality and hyperactivity of the skeletal musculature, the suggestion was not checked experimentally until the present day. Work with young children (113) has shown significant correlations between high muscular tension and ratings of "lack of stability," "nervousness," and "jittery reaction" made by teachers and physicians. College students (71) also showed positive correlation between muscular tension residuals in emotionally displacing situations and ratings of irritation and lack of nervous control. The degree to which a person lacks control over muscular relaxability can be reliably estimated during the rest (38, 146). Mention is also made of those studies (36, 37), showing the relation of heightened involuntary muscle tension to disorganized performance, of muscular tension while in the act of writing to psychoneurosis and combat fatigue (147).

The most fruitful attack on the neuromuscular control factor has been the study of the relation of skeletal discharge processes to the autonomic arousal processes in experimentally induced frustrations. In certain preliminary attempts to study this relation, evidence from normal subjects (77) suggested that individuals who recover internal equilibrium quickly (as measured by rapid return of palmar skin conductance to a prestimulus base) show a high degree of externalized activity (as measured by increased restlessness, talking, etc., during stimulation). Since one of the alleged factors in psychotic disorders is a discrepancy between aroused excitation and its appropriate external expression, the same experiment was repeated on two representative psychotic groups (78). Comparisons showed that manics as a group had greater internal arousal and greater overt discharge than normal subjects, whereas schizo-

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phrenics were aroused no more than normals. Ideational and sensory displacements affected arousal and recovery factors somewhat differently in the two psychotic groups, but these physiological reactions were more diagnostic of the duration of the psychosis than of its classification. Because of the variability within this group, the correlation of physiological recovery with motor discharge was less for psychotics than normals.

A fundamental defect in the foregoing studies is that the measure of overt discharge does not take into account all types available to the subject; more especially, they do not attack the problem of the *specificity of discharge*. In attaining homeostatic re-equilibration more than mere quanta of discharge need to be considered. Attention must also be given to *appropriateness*, here defined as the degree to which an overt response is specifically adaptive to its initiating cause. Such measures of appropriateness were first attempted by Luria (105). He recorded both the amount of specifically directed motor activity and the non-specific movements of the unused hand during conflict situations, but failed to quantify the specific-general discharge ration. Recent attempts at such quantification have been made with typists (1) and with children (69, 99) in competitive situations. Results indicate that subjects who discharge relatively more of their aroused energies through the motor channel specifically appropriate to the experimental displacement also tend to recover equilibrium quickly, and to be left with only small amounts of residual tension.

The studies mentioned indicate that control of the overt discharge of aroused energies is a measurable and important aspect of personality pattern. Yet the bodily mechanisms primarily responsible for the adequacy or inadequacy of

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this discharge are not revealed. At present we can only advance the following tentative suggestion.

According to the theory underlying this approach, overt behavior is considered as a means of discharging, in as co-ordinated fashion as possible, bodily energies developed by internal needs and associated external conditions. Behavior is also regarded as functioning to maintain homeostatic balance of the total organism. Since the specificity and adequacy of discharge are largely set by training, the centers of directional control are presumably located within the central or exteroceptive nervous system, possibly in the frontal lobes. Many studies have reported the lack of directional motor control, the absence of inhibition, and the excessive skeletal activity in persons and animals deprived of the frontal lobes. There is also evidence of behavioral improvements in certain psychotics where frontal lobotomy has freed the patient from too great inhibition of reaction-discharge. The central nervous system would thus seem to control the discharge factor, just as the autonomic system tends to control the arousal aspect of personality structure. The central nervous system and its associated exteroceptors appear to operate through the elevating and depressing processes of excitation and inhibition over all channels of motor discharge, or the complete ascendancy of the excitatory process would interfere with the orderly progress of homeostatic equilibration.

The question of significant constitutional differences in discharge-control cannot be answered at the present time. It is probably true that the more the internal physiological arousal, the more difficult is the control of its externalized expression. The tendency toward overflow and diffusion of energy in nonspecific discharges will probably be greatest in persons highly aroused by stimulation. But it is by no

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means axiomatic that as bodily arousal increases, control over its overt expression must necessarily deteriorate. The internal and external aspects of the homeostatic process are somewhat independent factors. Some persons, perhaps because of an inherently powerful central nervous control, always seem able to channelize aroused energy and express it in a co-ordinated fashion; though highly aroused they are still judged as "poised," "masters of the situation," and "resourceful." Because of this independence of arousal and discharge mechanisms, it is possible for a given situation to produce either the socially valued response of the genius or the nonapproved response of the psychotic.

Bodily Factors in Homeostatic Variability. Another prominent factor in personality differentiation appears to be the variability of the processes used in homeostatic re-equilibration. While not of the same order as arousal and discharge-control factors, its measurement may have the greatest practical significance. Some individuals, when displaced by similar stimuli, mobilize and discharge their energies with considerable constancy; both the amount of arousal and the character of the behavioral discharge can be predicted with the same accuracy. Other individuals are highly variable on one or both of the factors; not only is their behavior erratic and unstable, they also tend to fluctuate in the maintenance of basal levels of reactivity. The variability in types of overt reaction might be due to errors in early conditioning, as for example, an act approved one day which received severe punishment the next. But the inconstancy of basal maintenance processes is not so easily laid at the door of "experience."

Some inadequacy of hormone control, autonomic balance, or other constitutional factor is probably responsible for homeostatic variability. It may be that unstable equi-

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librators are not well knit or integrated physiologically. Or perhaps they are attempting to stabilize their internal milieu in relation to the external world at an abnormally high level or low level of energy expenditure; this would place them—in terms of elevating and depressing mechanisms—well on the plus or minus side of the normal range of autonomic balance. It is presumably true that organismic stabilization is more difficult to maintain at the extremes of bodily reactivity and that reactions will be more variable in such cases (optimal reaction range).

It should be noted that whereas normal and psychotic groups are not significantly differentiated in terms of physiological arousal and recovery to resting levels of activity, psychotics as a group are less variable (more rigid) in their reactions (78). The greatest degree of homeostatic variability appears to come not from the normal or psychotic groups but from psychoneurotics. The latter group, more than any other, has difficulty in maintaining homeostatic constancy even under conditions of rest. While the suggestion needs confirmation with more cases, it would appear that physiological variability is a very significant aspect of unstable personality structure. It is worth noting in this connection that variability in basal physiological activity levels has been found to be positively correlated to rater-judgment of "irritability" in overtly expressed action (71, 72). If a reliable measure of homeostatic variability is ever attained, it may prove more diagnostic than any other indicator of individual difference in health and disease. Already we have reached the state where medical examination of military personnel must pay some attention to composites of measurement as well as to single variables. *Physiological Interrelations in Personality Pattern.* The beginning of this chapter emphasized the pattern concept of

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personality, but opened the way to analysis of the major axes of differentiation through study of neuromuscular homeostasis. Obviously, the present limits of this work are not adequate to a complete appraisal of the individual personality structure. With the idea of attacking "first things first," situations demanding energy mobilization and discharge were purposely set to emphasize "temperament" rather than the "intellectual" aspects of personality. The extensive work in intelligence testing has already given considerable understanding of this particular parameter of personality differentiation.¹⁴ It is presumed that, on the physiological side, an individual's *discriminative capacity* is somehow related to the ability of his associative nerve centers to use the products of metabolism to advantage, but that this third "discriminative" factor is never free from the two basic motivational and temperament factors, "drive arousal" and "discharge control."

The uniqueness of the individual personality pattern is conceived, then, to depend upon the interaction of quantitative gradations in such factors as *discriminative capacity*, *drive arousal*, and *discharge control*. A visualization of such patterns should somehow relate these major axes of differentiation with each other and make it possible to show each individual's position with reference thereto. The nearest we could come to such a scheme would be to construct the various axes of differentiation orthogonal to each other, and then use a multidimensional sphere whose radius is unity to include all members of the population within its

¹⁴ Performance tests of all sorts naturally reveal large numbers of distinct variables when analyzed factorially. The current tendency to see a "G" or general intelligence factored into "number," "verbal," "space," and the space component further factored, etc., should not obscure the possibility that some single psychophysiological variable lies behind a number of factors revealed by statistical manipulation of performance test scores.

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confines. As indicated by Figure 10, the greatest number of people would be represented as dots near the center where all axes intersect. The deviates would be represented in more outlying areas. Although an oversimplification, such

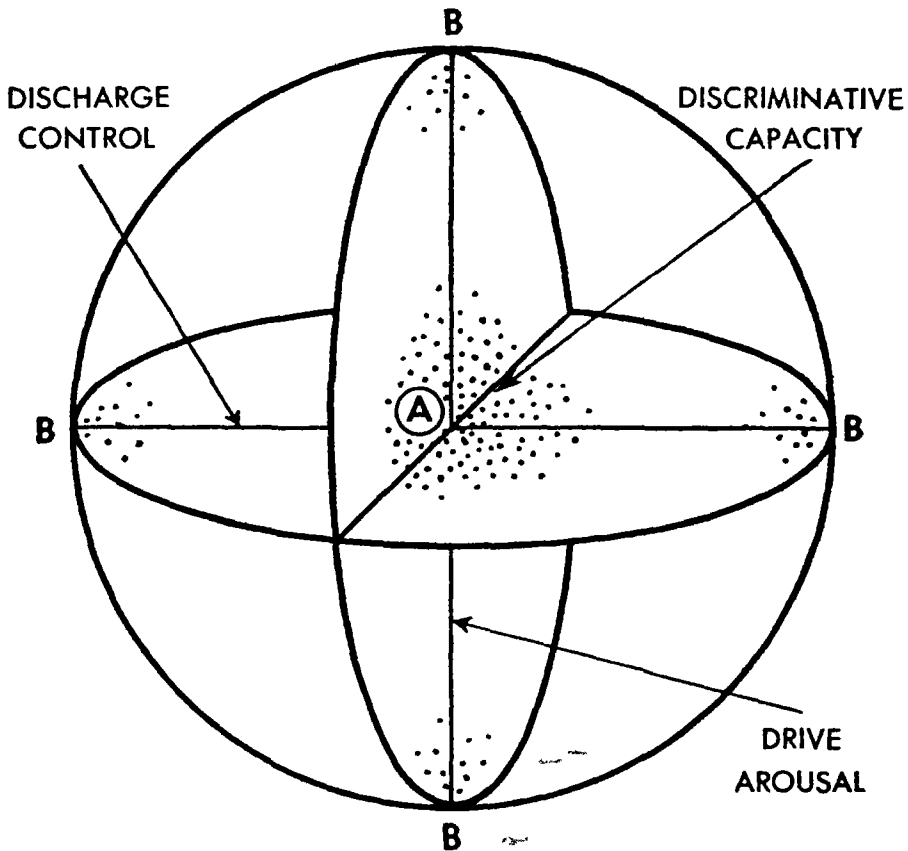


Figure 10. The personality sphere, showing three major axes of difference.

a figure would indicate that the individual is always an organized totality or pattern and not a mere aggregate of conflicting positions on linearly represented normal curves of "trait" distribution.

Our present explorations of neuromuscular homeostasis provide, of course, an insufficient basis for the actual con-

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struction of the schematic figure just proposed. We are by no means certain how many parameters will ultimately be required to account fully for variations in personality structure.¹⁵ Even the presumed factor of discriminative capacity was largely ignored in existent studies; but this had the advantage of permitting a study of the interplay of two factors, drive arousal and discharge control, with considerable profit. The patterning of these two factors has been observed in connection with selection tests of civilian and military personnel and with psychoneurotic cases. The results, though sketchy and incomplete, indicate that certain well-known clinical types can be identified with reference to these interactions.

In Figure 11 we have represented by the letters ABC, etc., persons possessing different personality patterns because of the interaction of drive arousal and discharge control factors. Before discussing each particular pattern designated, it should be mentioned that we are assuming arousal and discharge measures to be a representative sample for each case discussed. We are well aware that the arousal value of a stimulus is determined by previous conditioning, as well as by some more inherent factor such as available energy. In other words, it is the general differences in neuromuscular homeostasis which enter the present scheme, and not the specific differences caused by stimuli of varied interest and significance.

A represents the position of the superficially calm and collected individual of median arousal whose higher nervous centers naturally or by training exercise a high degree of inhibitory control over skeletal responses. This tends

¹⁵ In an appraisal of individual differences for selective purposes, at least two additional parameters have seemingly been uncovered. Cf. G. L. Freeman and E. K. Taylor, *Pick the Leader*, Funk and Wagnalls (in press).

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to block socially inappropriate or untimely overt discharge. Aroused energy may in these cases be directed toward the smooth muscles and other tissues which are not under such a degree of inhibitory control as are the striped muscles. Heightened activity in smooth muscle tissue may help

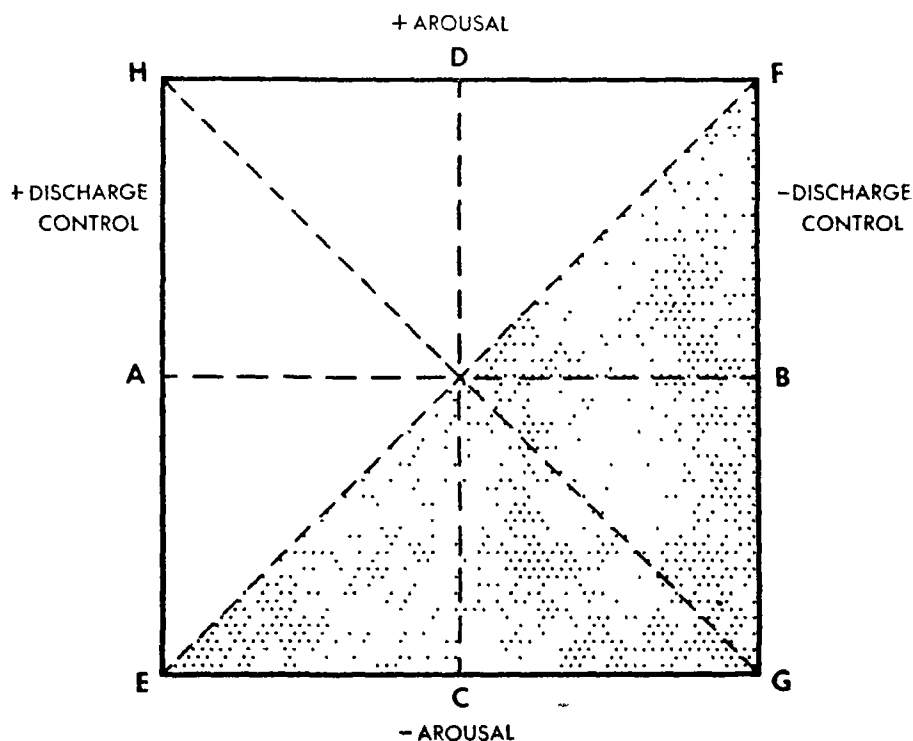


Figure 11. The dynamic interrelation of two axes of personality differentiation.

relieve the system of some of the unexpressed excitement, and such an individual may make some overt adjustments which have social approval. The fact remains, however, that he is physiologically unbalanced. His nervous system is being restimulated and, if these self-reinforced tension effects pile up, the level of organismic reactivity may be pushed beyond optimal limits, causing breakthrough to

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such violent over-reactions as an ax murder. As an alternative individual *A* might develop a serious colitis or gastric ulcer and never realize that defective homeostasis was the basis of his disease. All consequences come back ultimately, in Individual *A*, to a sufficient energy mobilization with excessive inhibition over the channels for its discharge.

B is the superficially nervous individual whose directional control of overt skeletal discharge is fundamentally weak, or at least underdeveloped. He fidgets, engages in useless and excessive movements, and is often referred to as the "jittery type." While he is often given to anxiety, *B* is likely to have a calm digestive system and lower activity levels in smooth muscle tissue than does individual *A*. Several consequences may be inferred for *B*, but the essential analysis here is one of average energy mobilization with poor directive control.

C is an individual whose autonomic mechanisms of arousal are fundamentally weak. He does not mobilize sufficient energy to allow his higher nervous system to function effectively in difficult situations. He "gets mad, but not mad enough" and is often forced to use socially inadequate methods of ideomotor (phantasy) discharge for want of energy to carry out more appropriate reactions. The essentials of this pattern are possession of average directive control but low drive arousal.

D is the energetic person with excessive energy mobilization and average discharge control. In contrast to the person mentioned as *C*, he gets too mad in a crisis. If he releases the excess energy into enough diverse channels, this individual may not attract attention to himself or be classed in any way as abnormal. If he fails to give equitable discharge, the arousal system may itself break down and result

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in the typical schizophrenic insensitivity to environmental press.¹⁶

E is an individual of high control and low arousal. An exaggerated case of *A*, such a personality's inadequacies are largely due to lack of drive. High discriminative capacity would probably cause anxiety symptoms to appear in *E*. If lacking in intelligence, *E* would be phlegmatic, vegetative, and unproductive.

F is an individual with serious discrepancies between arousal and control factors in neuromuscular homeostasis. An exaggerated case of *B*, the high arousal and low control may result in the manic type of personality disorder.

G is an individual of both low energy mobilization and low directive control. Such a person may show a proneness to develop disorders of the neurasthenic type which features withdrawal from disturbing situations.

H is an individual whose high control and high arousal (if accompanied by sufficient discriminative capacity) may produce works of genius. He has the potentialities of fine co-ordination of behavior discharge in the face of great energy mobilization.

The question arises as to which of the personality patterns described above should be regarded as abnormal. All are potential causes for concern. In theory at least, only the persons represented around the center of the graph have the most appropriate ratio of directive control to energy mobilization and so can meet adequately and recover easily from displacing stimulation. From such a cen-

¹⁶ This interpretation of schizophrenia is in line with Maslow and Mittelman's (*Principles of Abnormal Psychology*, 1945) concept of catastrophic anxiety, which is supposed to precede breakdown. Certain types, such as simple schizophrenia, may arise, however, from other arousal-discharge interactions besides the one mentioned in *D*.

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ter, deviate patterns are considered more or less acceptable according to the culture in which they appear. In a competitive society such as ours, persons falling within the area *HEF* are more likely to be regarded as "normal," whereas those falling within the shaded area *GEF* may be classed as "abnormal."

It is emphasized that the interactions discussed above are sketchy and incomplete. Several other axes of personality differentiation affect the total pattern. Chief among these, we presume, are the factors of discriminative capacity and homeostatic variability. Lack of intelligent self-perception may upset every arousal-discharge interaction that has been discussed. Instability can appear in homeostatic relations, maintained at any level of bodily arousal and for any degree or type of discharge control. Bodily arousal and its equilibration can be accomplished by relatively automatic mechanisms in some persons, almost regardless of the degree of displacing stimulation. Such persons should show stable neuromuscular homeostasis. Others may have to use in the same situation higher or lower orders of equilibratory adjustment mechanisms, the control of which is more variable and acquired.

Role of Physiological Methods in Personality Study. We come to the summary question: What do physiological methods contribute to the understanding and diagnosis of personality?

It has been our contention that objective measures of energy mobilization and discharge supply an essential base for the assay of personality structure. We began by pointing out that most psychologists now refer the uniqueness of the individual to the particular *patterning* of several "basic factors" or "parameters of differentiation." The fundamental weakness of this position is that the alleged fac-

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tors are vague and ill-defined. Assays based on the analysis of the individual's verbal responses to various expressive media and those of clinicians who observe him are not likely to solve the problem. At this level of attack, it is very difficult to segregate basic from superficial characteristics or to provide any sure means of validating the derived variables. That is why psychologists have long sought "bodily correlates" of their alleged personality factors and why they should welcome more finite analysis of the person in the limited and controlled settings of the laboratory.

The physiological study of reaction dynamics strikes at the heart of personality study through the observation of individual differences in neuromuscular homeostasis under standardized conditions of displacement. It makes no prior assumptions of psychological factors whose bodily correlates it hopes to uncover. Rather it proceeds from a reverse direction; physiological factors are assigned to cover the major variations occurring in the measures of neuromuscular homeostasis, and these are presented as a basis for checking the validity of factors derived from the psychological levels of description.

Of the several lines of behavioral attack upon personality differentiation, relatively little attention has been given to studies confined exclusively to the overt level of response. Covert indices of energy mobilization and discharge have been favored as more independent of the peculiarities of previous experience and of the experimental displacement. The search is for relatively persistent and typical bodily trends which can be used in checking the validity of such inventory-derived trait labels as "suggestibility," "dominance," and "emotionality," and the pertinence of such clinically derived pattern labels as "the exalted," "the persecuted," and "the melancholic."

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It is not thought that recordings of blood pressure, action potentials, and electrical skin responses will ever supplant grosser behavioral methods of personality assay. For example, if the relatively crude Rorschach projective techniques showed correlation with any basic variables of neuromuscular homeostasis, this would be considerable argument for its use in practical diagnostic procedure. On the other hand, any clinical diagnosis or psychological trait test which showed low validity when correlated with basic homeostatic variables might be considered as lacking an essential orientation in personality assay.

Most psychologists, psychoanalysts, and psychiatrists would probably agree that personality patterns are built up during life by the interaction of excitation aroused in individuals of specific biological constitution and varying degree of thwart or frustration imposed upon its overt expression by environmental circumstance. The use of physiological methods in laboratory studies of induced frustration might put a substantial floor under certain clinical methods which owe their present vogue mainly to the fact that they seem to work therapeutically. Likewise, many statistically isolated "traits" might fall into more meaningful patterns when cast against relevant physiological variables. Our knowledge of personality stands to gain from any procedure which links the field with the dynamic constructs of organismic biology. To this purpose we commend the further exploration of individual differences in neuromuscular homeostasis with the aid of physiological recording techniques.

Behavior Disorder and Therapy

The Problem of Behavior Disorder. So much has already been written on this topic that our own exploration can best be limited to organizing material pertinent to the homeostatic point of view. We have considered the organism as an energy system so structured that it reacts to changes which threaten the preservation of its essential constant states in such a way as to maintain those states. This means that the total organismic pattern may undergo change in order to re-equilibrate basic disturbances. We have seen that all the significant modifications of total behavior—including personality structure—result from the interaction of aroused excitation patterns and varying degrees of thwart or frustration imposed upon their overt expression by environmental circumstance. Now we shall consider how “abnormal” modifications are diagnosed and treated.

A basic tissue disturbance with an automatic re-equilibration leaves the total organismic pattern unchanged. But because man possesses a higher nervous system adapted to support and supplement limited organ homeostasis, he is continually anticipating threats to the constancy of his internal milieu and engaging in elaborate forms of motivated behavior which are calculated to stabil-

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ize and offset the threat of change in his external milieu. It is here that goal-directed activity meets thwart and that conflicting patterns of excitation require resolution. Some of the emergent forms of overt behavioral discharge will be considered "abnormal" because they are atypical for the society in which they appear; yet these deviations in behavior may well be homeostatic-regulatory, serving in some degree to readjust the individual physiologically. On the other hand, an individual who is thwarted in discharging aroused energies through socially approved behavior may develop substitute means of expression which do not attract disfavor, but which can be considered pathological in the sense that they are relatively inadequate equilibrators of the physiological disturbance.

Earlier in the book we have defined normal "best" adjustment as something of a compromise between a behavior pattern which has the highest social approval and one which is most physiologically equilibrating. Psychoanalytic theory recognizes that such an individual is balanced between the most direct gratification of his needs (pleasure principle) and the restrictions set by thought of consequences (reality principle). This view can be placed in a homeostatic context if we assume that a behavioral expression may be found for a given disequilibrium which will not be so atypical socially as to arouse more nervous tension than it releases or so atypical physiologically, as to discharge little or none of the original excitation.

The atypical psychotic personality thus becomes an energy system that has broken so completely from the checks of social reality that an extremely aberrant behavior pattern can be physiologically equilibrating. For example, the paranoid is not disturbed by the reaction of others to the flights of fancy, and a nondiscriminatory (rage) dis-

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charge leaves the manic physiologically relaxed and equilibrated instead of rearoused by the thought that his tantrum is discrediting in the eyes of his fellow men.

The neurotic, on the other hand, is still held in check by social reality. If he engages in equilibratory overt behavior, his appreciation of its aberrant character develops considerable re-excitatory tension. If, as is more frequently the case, he hesitates to make an outgoing type of discharge, he is equally upset. Such homeostatic unbalance exists in its purest form in "basic anxiety"—the root of most neurotic disorders. Whereas the normal personality, by socially acceptable behavior, and the psychotic, by socially unacceptable behavior, achieve physiologically satisfying adjustment, the anxiety neurotic, whether his overt behavior is approved or disapproved, overt or covert, is a truly maladjusted person with an excess of unexpressed tensions.¹

The concept that all total behavior is homeostatic-regulatory greatly expands the problem of behavior disorder. We shall need to examine many organic disturbances frequently treated as socially acceptable diseases to determine if the individual is using such devices for the homeostatic expression of emotional tensions occasioned by thwart and frustration. A growing appreciation of this point of view is found in present-day interests of physicians in psychosomatic medicine.

Separating the functional neuroses from the vegetative or organ neuroses is a false lead. So too are classifications based upon overt behavior manifestations alone. The latter

¹ For an elaboration of this general point of view, cf. M. Harrington, *The Management of the Mind*, Philosophical Library, 1943. Cf. also, M. E. Bitterman, "Behavior disorder as a function of relative strength of antagonistic response tendencies," *Psychol. Rev.*, 51, 378, 1944.

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makes for many strange bedfellows. A hebephrenic and a Buddhist may behave outwardly alike, yet probably present fundamental differences in bodily energetics. Defective homeostasis, particularly any discrepancy which exists between energy mobilization and discharge, constitutes a more essential key to the understanding of the problem of behavior disorder.

Symptoms and Causes. Modern ideas of symptomatology no longer treat the behavior maladjustment as if it were the sickness itself. Many different overt acts are recognized to have the same underlying cause. All kinds of suggestions have been made as to the fundamental cause of insanity. They range from hereditary predisposition to environmental press, from repressed infantile sexuality to acute thwarting of self-aggrandizement. Space does not permit examination of such theories. Here we shall simply reaffirm the position that all behavior tends to be homeostatic regulatory. Though it sounds deceptively simple, we see a basic cause of reactions considered "abnormal" in the blockage of physiologically appropriate outlets for the release of aroused excitation and a consequent re-distribution of energy through other tension systems.

The cause of an aroused excitation may be quite remote from the behavior which attempts to express and discharge it. Thus there has been much psychiatric delving into the individual's past, and relatively little effort at rerouting the discharge of unidentified tension systems. The argument for this approach to behavior disorder is that "insight" into the basic disturbance will aid in finding a more appropriate channel for its equilibration. This is satisfactory in so far as it goes. But there are distinct limitations to any method which depends upon the individual's ability to see behind his symptoms or which seeks to interpret for him his funda-

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mental conflicts. The frequent inability of an individual's higher nervous centers to redirect behavioral discharge when aided only by the verbal suggestion of another helps explain the prevalence of other diagnostic and therapeutic procedures.

Psychiatric Diagnosis. Psychiatrists, whose business it is to classify nervous disorders, have always been impressed by their variety. Controversies have raged over the legitimacy of "inner" as opposed to "outer" modes of diagnostic classification. Aside from differences in interpretation, however, little has been added to the Kraepelinian classification of long standing. After the personality changes which accompany organic deterioration in paresis, arteriosclerosis, and various somatic or toxic conditions are set aside, this leaves five types of so-called functional disorder. Epilepsy remains as an intermediate link between the organic and the functional.²

Descriptions of the five main types of functional abnormality (cyclothymosis, schizophrenia, true paranoia, psychoneurosis, and psychopathic personality) cut back and forth across each other as one reads through the maze of psychodiagnostic literature. At the present time we have a mixture of inner and outer characteristics of these personality patterns. Much overlap of classification is recognized and many subgroupings are found within large rubrics. Subclassification of psychoneuroses range from the outwardly disturbed expressions of hysteria, psychasthenia, and anxiety states to the diminished expressions of neurasthenia. In schizophrenia, subclassification includes (1) the arrested withdrawn state of simple schizophrenia, (2)

² Evidence that epilepsy involves a deeper neuro-physiological upset than functional psychoses is indicated in the disappearance of schizophrenia when epilepsy develops in a system (*Psychol. Bull.*, May, 1940).

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the regressed state of hebephrenia, (3) the systematized delusional state of the paranoid, and (4) the highly aroused and completely withdrawn catatonic state.

The fact that functional disorders yield to no simple classificatory system indicates the complexity of the behavioral observations on which they are based. Each clinical classification must be regarded as a pattern of interacting variables whose precise natures are largely unknown. In attempted simplification, the psychoses (manic-depressive insanity and schizophrenia) are often distinguished from the neuroses (hysteria and anxiety states). This separation is based sometimes on the degree to which the pattern deviates from the so-called normal personality and sometimes on the extent for which the abnormal behavior pattern involves the whole personality. The psychotic is said to have lost critical contact with reality, to have solved his conflicts by a most drastic limitation of response flexibility, and to be least capable of repatterning through a developed insight. The neurotic pattern, with the exception of anxiety states,³ also represents a terminal adjustment to a difficulty; but here there is more contact with reality, response flexibility somewhat approaching normality, less total involvement of the organism, and greater possibilities of re-education.

To an outsider, exposed for the first time to these behavioral depths, it appears that psychiatric diagnosis accomplishes its major result by winnowing out those "neurotic" cases upon whom it is practicable to initiate some form of psychotherapy. There is little evidence that treat-

³ It is presumed that anxiety states are usually prodromal to further behavioral maladjustment. The theory that both neuroses and psychoses develop from a common matrix of heightened and unexpressed tension is capable of experimental check.

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ment of the more severe psychotic forms of disorder is either aided or harmed by the present Kraepelinian classifications. Both a schizophrenic and a manic may react favorably to insulin injections, and this so-called "shock therapy" is no outgrowth of psychodiagnosis.

Physiological Diagnosis. Useful as is psychodiagnosis in certain cases of behavior disorder, the need for methods of broader base and wider usefulness has long been recognized. We have seen how the fading hope of total personality appraisal in terms of paper and pencil tests is being replaced by various "projective" techniques. We know also the disappointing history of body dimensions and static physiological measures in the assay of personality differences. Much of the latter work has shot wide of the mark by too great preoccupation with clinical classifications. Type of insanity is not the fundamental interest on the physiological level. The problem demanding primary attention is the *degree of physiological unbalance which accompanies an existent or incipient behavior disorder*. If just this much could be diagnosed, we might have the means at hand for setting up a more rational therapy and for evaluating its effects. Should we be able to go further, showing heightened and sustained physiological arousal as the regular accompaniment of the prepsychotic condition ⁴ and

⁴ It is significant that our best evidence for the value of physiological diagnosis comes at present from the electroencephalographic records which predict epileptic seizures. Study of this form of insanity, long regarded as the border line between the organic and functional disorders, opens the way for widespread measurement of energy mobilization and discharge. Exploratory recording of blood pressure and palmar conductance level made by the author and Dr. Leon Saul at the Institute of Psychoanalysis suggest that many hypertense patients become physiologically relaxed with the progress of their psychoanalysis, and it has long been recognized that lying on the cot facilitates freedom of recall in expressive verbal discharge. Possibly the muscular inhibitions ordinarily exercised in

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reactions to experimental displacement tests as valid precursors of breakdown, we would have a basis for prediction and control. The mental hygiene movement would know with more certainty the individuals on whom it should concentrate its preventative medicine.

A recurrent suggestion has appeared in the literature to the effect that some means should be found to test the individual's proneness to nervous breakdown. This phraseology would imply that some organismic energy systems have more difficulty in re-equilibrating basic tissue disturbances (or threats thereto) than do other systems. But the problem of homeostatic reaction, particularly at the higher nervous levels, is not a matter of a simple and inherently restricted set of factors. An extremely lonely environment may unbalance an essentially strong system, and many weak systems do not develop behavior disorders simply because they are never subject to sufficient environmental pressure.

From what we learned of personality differentiation in the last chapter, individuals vary with regard to (1) the amount of energy mobilized to meet internal needs and related external demands, (2) the degree of higher directive control exerted over the overt discharge of these energies, and (3) discriminative capacity. Overdevelopment or underdevelopment of any one of these three major axes of differentiation might result in defective homeostatic adjustment. It is also consistent with available information to suppose that some individuals meet frustration with insufficient energy mobilization to develop ade-

a state of attention are released, with the effect spreading to a weakening of inhibitions. All of this evidence, sketchy as it may be, favors a close connection between physiological diagnosis and "psychic" disturbance. Cf. J. Hadley, "Various roles of relaxation in psychotherapy," *J. Gen. Psychol.*, 19, 191-203, 1938.

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quate adjustments whereas others mobilize excessively and then fall into disorganized response. Again, the capacity to delay gratification or accept substitutes involves variations in discharge control. We may also recall that the higher nervous centers function most effectively over median limited excitation (optimal reaction range) and that the non-discriminatory behavior which characterizes most so-called "abnormality" is presumptively initiated by systems whose levels of action have exceeded their optimal limits. This hypothesis provides one base ⁵ from which to launch the physiological attack upon the problem of proneness to nervous breakdown.

Rather than attempt the difficult task of isolating the particular factors responsible for proneness to breakdown, we shall do well to examine only the general characteristics of the physiological approach. By means of experimentally induced frustrations, stress tests, and the like, we can face the organism with the need for making a homeostatic adjustment and then make measurements of the amount of energy mobilized, the degree of its return to a pre-existing base, the variability in this return at different times and occasions, and the variability of the basal level of rest itself. Slow recovery and variability in maintenance operations may indicate homeostatic inconstancy, and perhaps also the approach of the total system toward the (plimsoll mark) limits where socially inept and nondiscriminatory behavior will be utilized and perfected in the interests of physiologi-

⁵ Mention should also be made of Rosensweig's (*J. Abnorm. and Soc. Psychol.*, 37, 48-51, 1942) related measures of "frustration tolerance," and of the approach initiated by Pavlov. In this the animal is forced to make discriminatory responses of gradually increasing difficulty. The time taken to produce breakdown or its recovery might be taken as an index of proneness to breakdown. This conditioning approach has been combined with the one suggested above, with positive correlations resulting (61).

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cal complacency. The fact that such physiological methods of diagnosis are not dependent upon psychological contact with the patient suggests a widespread usefulness. Yet present data are provided mainly by subjects in laboratory situations. If one-tenth of the time and funds now devoted to psychiatric diagnosis were utilized for physiological study of neurotics and psychotics, we should soon be in a much better position to judge the relative worth of the latter approach.

The Neurotic Disorders. It is commonly held that the neurotic disorders represent less serious derangements than psychotic disorders, and that they yield more readily to therapy. Certainly the neurotic personality approaches the so-called "normal" individual in that it is still differentially responsive to variations in environmental stimulation, whereas the typical psychotic personality is so highly patterned and rigid in its response adjustments that irrelevant stimulation is either ignored or is responded to as if it were related to the dominant tension system.

In terms of our hypothesis, we might expect the neurotic to show evidence of deficient neuromuscular homeostasis when compared with the normal. What we find, of course, will be a function of the stimulus displacements that are used. To many displacements the neurotic may readjust as well as does the normal. Only when the stimulus has high arousal value or touches an area of low "frustration tolerance" will the neurotic show overt manifestations of unbalance and upset. With less disturbing stimuli our cues must come almost entirely from covert reactions. For instance, we should expect neurotic individuals to recover physiological equilibrium slowly following any emotional displacements due largely to an inability to discharge the aroused tension completely and adequately. It is charac-

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teristic that such neurotic symptoms as hysteria, tics, and habit spasms tend to be self-maintaining; that is, the behavior restimulates the organism. This seems especially true for the hypersensitive excitation background of anxiety states. Vegetative or organ neuroses might also be interpreted as attempted expression of emotional tension that is relatively nonequilibratory and self-perpetuating. From the standpoint of total behavior energetics, the picture throughout is one of physiological imbalance. An organismic energy system which vacillates between the highly discriminatory adjustments of the well-adjusted personality and the nondiscriminatory adjustments of the typical psychotic also reveals physiological inadequacies, so far as the totality of homeostatic adjustment is concerned.

The Psychotic Disorders. Those two great classes of psychotic disorder, schizophrenia and manic-depressive insanity, would seem to be similar from the homeostatic standpoint in that both represent physiologically adequate equilibration of tensions associated with thwart and conflict of goal-directed activity. Furthermore, they are fully adjustive. The psychotic picture of energy mobilization and internal recovery could closely resemble that of the normal, even though the external discharge pattern might be non-discriminatory, highly individualized, and of very limited scope. The psychotic disorders can be regarded as highly perfected habits and ready avenues for the discharge of aroused excitation. These discharge habits dominate the total organismic pattern, and all types of stimulation, if effective in causing arousal, are reacted to by means of the fixed system. Although bodily arousal may have been high in the prepsychotic state because of unexpressed tensions, the patient may now relinquish responsiveness to a wide range of stimuli and readjust as a totality on a lower energy

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level. Presumably, the longer the psychotic type of adjustment holds sway, the more completely and deeply ingrained does the habit become (physiological level of response adjustment). It has been noted that the success all forms of behavior therapy have is indirectly correlated with the duration of the disorder undergoing treatment. This can only mean that a homeostatic adjustment, first acquired by more superficial layers of the neuromuscular system, in time reaches down to "set" more and more basic systems. Eventually the habit system of postural fixation of the persecuted, or the melancholic, or the exalted is represented by a complete repatterning of the internal milieu, including restructurization of glandular controls. Small wonder, then, that profound physiological shock, such as is provided by an insulin injection, is often the only method of breaking through a well-established form of nondiscriminatory adjustment behavior.

Physiological Study of Neurotics and Psychotics. The last chapter showed differentiation of so-called normal subjects according to rate of physiological recovery from experimentally induced displacements. There was indication in that work that persons regarded as emotionally unstable and subject to neurotic symptoms had low physiological recovery, high variability, and a discrepancy in the ratio of arousal and discharge factors in neuromuscular homeostasis. It was later possible to extend those observations to limited groups of neurotic and psychotic patients. In the latter study (78) only two types of stimulation were used (sensory startle and verbal associations involving recall of previous frustrations and conflicts). The neurotics were five anxiety cases who at the time of the tests were under the care of a psychiatrist. The psychotics consisted of 22 manics and 18 schizoids carefully chosen from state hospital in-

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mates upon the basis of generally agreed diagnosis. As with the group of "normal" subjects studied earlier (78), records of palmar skin conductance and general restless movement were recorded before, during, and after the experimental displacements. Psychotics as a group presented about the same rate of physiological recovery as did the normal subjects, a fact indicating that this group had achieved a high degree of internal complacency in homeostatic adjustment. There was no significant difference in the average degree of energy mobilization for the two types of psychotic disorder, a finding which argues that the difference between manics and schizophrenics is largely one of the amount of inhibition exerted over the overt discharge of aroused excitation. Greater differences in energy mobilization and recovery were found within groups classed as manics and schizophrenics than were found between groups. While the average scores for the psychotic group were not significantly different from the average for normal subjects, their range was significantly greater for the psychotics. Individually, the psychotic patients were no more displaced and no more variable in their physiological reactions than were the normal subjects. But the neurotic group showed by far the greatest individual variability in neuromuscular homeostasis and the slowest physiological recovery from experimental displacements (72). On the assumption that reactions to experimental displacement are a reflection of the general homeostatic condition of the organism, it appears that the anxiety neurotic shows a greater discrepancy between energy mobilization and its discharge than does the fixated psychotic or the more flexible normal subject. The finding that the longer a psychotic had been confined in the hospital, the less energy he mobilized to meet new stimulus demands argues for shock therapy. Such

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physiological shock as is produced by metrazol and insulin injections or by artificial fever may help develop the patient's latent energy with enough force to render old discharge methods inadequate and to produce a "break-through" into new action.

"Choice" of Neurosis. Here we are interested in the factors responsible for the appearance of a *particular* neurotic substitute reaction symptom in an individual who is attempting to discharge blocked nervous tensions. For one reason or another, the specifically adaptive reaction is blocked in the neurotic personality and the residual tension pattern must find some expression through other channels. Various types of substitute discharge may be attempted before one is "chosen" and "perfected" as a means of evading greater difficulty.

The factors accounting for the emergence of a particular symptom in the neurotic personality are many. In a field largely untouched by definitive research, it is thought that hereditary predisposition, fortuitous conditioning, and other factors affecting the general level of available energy may all be involved. Thus one patient may "express" anxiety and his conflicts in motor automatisms and skeletal action because he has the high energy level which will support such metabolically costly discharge, while a less robust patient may "select" one of the psychasthenic debilities. A patient with a congenitally weak heart may find his unequilibrated tensions attempting to discharge themselves through this organ, thereby producing a cardiac disorder. Or the particular organ neurosis may result from an occupational predisposition (occupational neuroses), as when a habitual speaker develops neurotic symptoms associated with the speech apparatus. In all cases, however, the symptom discharge persists because it is partially equi-

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librating to a total organismic disturbance. Some psychiatrists⁶ are inclined to believe that the nature of the emotional conflict may be told from the organ system affected. The argument runs somewhat as follows: every organ has a certain expressive value common to all people (i.e. disgust expresses itself in vomiting, anxiety in pallor or diarrhea); accordingly sensory defects (hysterical anesthesia) denote conflicts between the individual and the external environment while disorders involving mucous membranes (oral, anal, and genital zones) express conflicts within the individual. Psychoanalytic writing has also contributed largely to the same hypothesis. Freud and Deutsch⁷ also suppose that the fixation point in the various stages of psychosexual genesis determine the type of neurosis. This view reaches its logical absurdity in writers who read a specific psychoanalytic interpretation into every type of action, including motor automatisms.

Many strict organicists⁸ would reverse the relationships proposed above, and believe organ difficulties are directly responsible for the total neurotic condition. They would have an organ change, such as occurs in the vaginal epithelium at menopause, the sole cause of a "psychic" frigidity. A compromise position⁹ recognizes that while every neurosis has an organic base, such as a vasomotor disorder, not every person who suffers a vasomotor disturbance has a neurosis. The "choice" of organ neurosis would therefore

⁶ H. Zweig, "Das Leib-Seelenproblems und seine Auswirkungere der Medizine," *Zentral f.d. Ges. Neurolen Psychiat.*, 61, 1-35, 1931.

⁷ F. Deutsch, "The choice of organs in organ neurosis," *J. Psychoanal.*, 20, 252-262, 1939; S. Freud, *New Introductory Lectures on Psychoanalysis*, Norton, 1933.

⁸ F. Kennedy, "The organic background of the psychoses and neuroses," *J. Amer. Med. Assn.*, 107, 1935, 1936.

⁹ P. Schilder, "The somatic basis of the neuroses," *J. Nerv and Ment. Dis.*, 70, 502-519, 1928.

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be explained by finding the special life situation where a tendency to specific disorder and a general undischarged emotional tension were first connected. It is pointed out that even a transitory disturbance of some bodily part, such as a bruise, may be fortuitously conditioned as a discharge mechanism for an originally unconnected emotional tension, so that pain and paralysis will persist even after the abrasion has healed.

Implicit in much of the writing upon neurotic habit-symptoms formation is the suggestion that aroused excitation, denied specifically adaptive discharge, recruits autonomic reinforcement, and becomes a self-maintaining "emotional" tension system.¹⁰ This tension system may be regarded as a symptom of mobilized but relatively undischarged energy. It may concentrate its circular action in a limited organ system, producing tachycardia, asthma, intestinal spasms, colitis, or ulcer; thus arise the vegetative or organ neuroses. Another path of circular discharge that the tension system may establish is through some level of action of the skeletal muscular system; here the autonomic disturbance is likely to be more generalized and the specificity of the discharge mechanism indicated only as a persistent tendency to ideomotor "phantasy," motor tics, and automatisms, or verbomotor behavior.

What determines a particular "choice" has not been answered in the very extensive literature on neurosis. Yet there are some helpful suggestions. For example, a woman who had a latent condition of *herpes labiales* had this old

¹⁰ A. H. Maslow and B. Mittelman (*Principles of Abnormal Psychology*, Harper, 1945) point out the nuclear operation that must underlie any psychosomatic affect—a continuously discharging autonomic nervous system which eventually stimulates affected organs to such a degree that they develop pathological conditions; cf. also F. Alexander, *Psychoanal. Quart.*, 3, 501–588, 1934, and L. Saul, *Psychosom. Med.*, 1, 153–161, 1939.

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disease redeveloped to an active state (sufficient for her blood to infect a rabbit) as a result of an insolvable personal conflict induced by hypnosis.¹¹ This experiment argues for predispositional factors which are aroused by the induced emotional tension, and hence serve as partial release mechanisms. Where there is no past history of disease, the mobilized energy may well be shunted to a constitutionally weak organ;¹² that is, a weak organ system while tending to work as a unity might have its normal rhythm of action interfered with by excitation from another source. The evidence of similar neurotic symptoms in certain families provides some support for this hypothesis.

Another type of constitutional factor might work indirectly in the choice of neurosis. Certain writers¹³ have pointed to the general scarcity of available energy in the neurasthenic type. Since certain discharge mechanisms (in ideomotor phantasy) can be activated with less energy than others, these might be selected for that reason. Or there may be a predisposition to great central nervous inhibitory control of discharge which precludes in certain persons the occurrence of skeletal muscle contractions, hysterical paralysis of symbolic content, etc. In the first world war hysterical illnesses were reported¹⁴ to be more common among enlisted men, whereas the more discerning

¹¹ R. Helig and H. Hoff, "Über psychozene Anstehung des Herbes labiales," *Med. Klin.*, 24, 1472, 1928 Cf. also B. Mittelman and H. C. Wolff, *Psychosom. Med.*, 1, 271-292, 1939.

¹² The opposite hypothesis, that the organ of *strongest* resistance will carry the extra tensional load, appears to be denied by the probability that a strong organ can discharge added excitation (like a lightning rod) without manifesting any persistent residual symptoms.

¹³ P. Janet, *The Major Symptoms of Hysteria*, Macmillan, 1929; E. R. Guthrie, *The Psychology of Human Conflict*, Harper, 1938.

¹⁴ H. L. Hollingworth, *The Psychology of Functional Neuroses*, Appleton, 1928.

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officers tended toward anxieties accompanied by visceral symptoms. This was perhaps an indirect consequence of the realization that a lack of control over externalized hysterical symptoms would not have been "acceptable" in an officer. Blocking of the hysterical expression of "fear" often causes a redirection of the energy pattern into expressive mechanisms not so open to public observation.

Since constitutional predisposition will not alone account for choice of neurosis, we must fall back upon fortuitous conditioning in our final analysis. The opinion has been expressed ¹⁵ that the first reaction to a stress situation (in which no habit is available for removing the condition responsible for the maintained tensional state) is a spread of excitation. In many situations this is very disruptive, producing what has been ¹⁶ rather bizarrely called "free floating fear," or an intransitive state of tension. By chance occurrence this diffuse excitation may find a partial discharge outlet, and so the tension focalizes in a particular organ or attaches itself to a particular action of symbol in close temporal relation to the initiating conflict situation. If the association is reinforced by parental example, by training that rewards the fortuitous discharge, or by persistent blocking of other outlets, it is learned as a symptom.¹⁷ That the patient is unaware of the relation, even though the symptom becomes a persistent habit, is irrelevant to the mechanism of fixation.

The individual's proneness for a particular type of neurosis has not been subjected to experimental investigation;

¹⁵ A. L. Luria, *Nature of Human Conflict*, Liveright, 1932, E. R. Guthrie, *The Psychology of Human Conflict*, Harper, 1938.

¹⁶ H. Harrington, *A Biological Approach to the Problem of Abnormal Behavior*, Science Press, 1938.

¹⁷ R. Stoghill, "Neurosis as learned behavior," *Psychol. Rev.*, 41, 497-507, 1934.

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yet the experimental conflict situation offers possible means of test. If the activity changes of different visceral and skeletal systems were recorded simultaneously during frustration, we might find a tendency for aroused excitation to be expressed more fully by one discharge outlet than others, or to be more residual in a given reaction system following removal of the stimulus. Such differences in tension discharge types might not, of course, prove sufficiently differentiating to predict exact "choice" of neurosis, but it would be an opening experimental wedge into one of the most important problems of behavior disorder.

The Problems of Therapy. All the diagnostic classifications of behavior disorder were developed, supposedly, as an aid to more effective therapy. Yet there is little evidence that existing classification systems have been of much use. This seems due largely to the fact that classifications deal with overt behavior symptoms, with little or no attempt made to range individuals along such quantitative physiological continual as reactivity level, variability of homeostatic reactions, or rate of recovery from stimulus displacements. Again and again some therapy that has been claimed as specific to a given syndrome has been found useful in an apparently different case.

In almost any school of psychotherapy, and certainly in objective behavioral attacks, two primary aims are evident. These are *release* and *reorientation*. The disordered person, whose equilibratory reactions have been thwarted in some degree, requires either the reduction or redistribution of aroused energies. There are a number of possible ways to achieve release, and we need not be especially concerned with the individual peculiarities of method. In simplification, we shall discuss four types of therapy. These are expressive psychotherapy, environmental ther-

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apy, physiotherapy, and "shock" therapy, and each may be related to the principle of homeostasis.

Expressive Psychotherapy. Although not usually discussed in such terms, psychoanalysis is the oldest form of expressive therapy.¹⁸ Here a neutral situation is set up in which the individual has freedom to react, verbally at least, to tension-producing conditions without fear of embarrassment or the inhibitory restraints that ordinarily cause him to hold his tongue. Uncritical listeners are rare in personal relations; hence the psychoanalytic hour, in which the patient may "project" his true self and release his feelings without guilt or anxiety, is most restorative. This form of physiological equilibration, known as "catharsis," is an aspect of therapy common not only to psychoanalysis but also to "relationship," "expressive," and "permissive" therapy—to say nothing of the Catholic confessional and the proverbial "good cry."

In psychoanalysis, release is accomplished by "catharsis" and "abreaction"; the patient, by means of a "repetition compulsion" is enabled to assimilate traumatic experiences. We can dispense with the particular symbolism and inner meaning which the psychoanalyst helps the patient read into his expressive behavior. Up-to-date psychotherapy is

¹⁸ Psychoanalysts prefer to describe their method as "analytical." As Freud's shadow lengthens, however, there is a growing realization even among his followers of the *expressive* value of psychoanalytic therapy. The patient soon learns to associate the type of material that the analyst finds most significant, and even the expression of an old conflict in a novel setting may accomplish tension release. Current accounts stress the importance of *working through* a conflict within a therapeutic relationship. Insight reached in solitude can stir up anxiety; accepted by the therapist, however, it is equilibrating and tension reducing. Re-education follows this release. On the importance of new learning in psychotherapy cf. L. F. Shaffer, "The problem of psychotherapy," *Amer. Psychol.*, 2, 459-467, 1947.

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shifting from discussions of ways to "give the patient insight" to ways to help him achieve it for himself. One great advantage that the new "relationship" and "expressive" therapies appear to have over classical psychoanalysis is that they permit the emergence of more individualized patterns of projected reaction tendencies.

In "relationship therapy,"¹⁹ opportunity is provided for the individual to find his own equilibrium in a situation which has both freedom and limits. In "play therapy," both children and adults can express themselves through art work and other material,²⁰ "author" their favorite comic-strip characters in newly created episodes,²¹ interpret and explain themselves by responding to auditory sounds,²² and even carry through a very convincing psychodrama.²³ "Expressive therapy" may also occur as a "product" of projective methods, used primarily for personality diagnosis. Thus a patient in interpreting the Rorschach ink blots may see in them what it equilibrates him to see.

Self-diagnosis is closely linked with therapy in all these approaches. Consequently, their use is limited to cases in which cerebral management and discriminatory reaction are still possible. As these constitute the largest group of

¹⁹ C. Allen, *Modern Discoveries in Medical Psychology*, Macmillan, 1937.

²⁰ L. Bender, *J. Genet. Psychol.*, **49**, 254-261, 1936; D. M. Levy, *Amer. J. Orthopsychiat.*, **67**, 37-96, 1933; J. H. Conn, *Mental Hygiene*, **23**, 49-69, 1939; E. H. Erickson, *Psychoanal. Quart.*, **6**, 139-214, 1937; S. Rosensweig and D. Shakow, *Amer. J. Orthopsychiat.*, **7**, 36-47, 1937; H. A. Murray, *Explorations in Personality*, Oxford Univ. Press, 1938.

²¹ E. Haggard and H. Sargent, *Psychol. Tech.*, **3**, 9-12, 1941; E. Haggard, *Char. and Person.*, **10**, 289-295, 1942.

²² S. Rosensweig, *J. Abnorm. and Soc. Psychol.*, **37**, 40-51, 1942.

²³ J. L. Moreno, "Psychodramatic shock therapy; a sociometric approach to the problem of mental disorders," *Sociometry*, **2**, 1-30, 1939; cf. also, D. Blain and F. Powdermaker, "Convoy fatigue and traumatic war neuroses in seamen," *J. Lancet*, **63**, 402-408, 1943.

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persons needing assistance, the various "talking out," "playing out," and projective techniques have an extremely important role in the release and redirection of neuromuscular energies.

Considerable work needs to be done before the relation of the expressive "psycho" therapies to homeostasis is fully clarified. Residual tension is presumably high in persons sufficiently aware of their maladjustments to seek aid from the psychiatrist.²⁴ It should be possible to measure how much "release" of physiological tension is accomplished by talking out or playing out emotion-producing problems.

The question of "insight" is not as complicated at the behavioral level of description as it might seem. Our discriminatory reactions are habitually directed to the seeing of relations between objects in the world about us. Yet they can be, and often are, directed to analysis of the organism's relation to its environment. Such "insight" is not a function of high discriminative capacity, since it can be achieved by children and illiterates. The psychotherapist sets the stage which favors the emergence of confused and vague ideomotor action as a verbal discharge. The patient hears his own verbal formulation of his problems or conflict and is able to react to it with new discriminatory "insight."

This view substitutes for the Freudian analogy of repressed conflicts brought out of the unconscious cellar and made presentable by insight in the conscious parlor, an analogy of confused and cloudy reaction tendencies brought out of the fog by verbalization so that the individ-

²⁴ The patient's desire for help is recognized as fundamental in psychotherapy. He must find his tensions and symptoms sufficiently unsatisfactory (i.e., disequilibratory) to overcome a natural reticence to seek aid from a stranger and to make the effort needed to redirect his energies. Alternation between need to readjust and desire to retain a symptom is frequently noted in the early stages of expressive therapy.

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ual may discriminate his reaction more "insightfully." It has long been the contention of motor psychologists that "thought is not thought" unless it can be verbalized. Much ideomotor action is confused and sketchy. Only when aroused excitation is expressed verbally are we able to make a critical evaluation of a reaction tendency. This is what is accomplished when an individual gains insight. The fact that many a patient becomes sufficiently equilibrated under such circumstances to say "Now I know what to do about it,"²⁵ bears testimony to the fact that something definite has happened in his bodily economy. Perhaps it is only that tension is redistributed and a greater degree of balance restored. Homeostatic doctrine recognizes such redistributions with discharge at the ideomotor or verbal levels. Energy mobilized by antagonistic systems of repression and conflict is thus made available for normal functioning. Patients whose energy distribution was formerly unfavorable to discriminatory reaction and higher directional control are now able to get hold of themselves. Goals and motives are shifted. If new choice of action also results, as it frequently does under this treatment, the restoration has a good chance of being self-perpetuating. At this point, the patient might well be given some knowledge of the homeostatic regulation of his system and of how to handle energy mobilization and discharge.

It appears that the major principle behind all expressive therapy is the setting of a stage on which the individual can bring about his own tension reduction or redistribution by overt behavior in relation to some neutral medium. On this he "projects" and presumably "solves" his conflicts. Present evidence would indicate that the practical plans

²⁵ H. Sargent, "Nondirective counseling applied in a single interview," *J. Consult. Psychol.*, 7, 183-190, 1943.

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that emerge in these situations are often more individually suitable and potentially equilibrating than any "canned" suggestion or personally colored interpretation that might be handed out. Allen²⁶ in psychiatry and Rogers²⁷ in psychology both emphasize the trend toward expressive techniques that free the patient to readjust.

Environmental Therapy. Another type of therapy may also be used with patients who have not completely lost their discriminatory powers (including contact with reality). This is usually called environmental or milieu therapy. It consists in removal of or from exciting situations, and substitution of new stimuli for the release of tension. Here belong the reconditioning and experimental extinction techniques that try to control the learning situation in such a way that undesirable reactions are detached and new ones acquired. This applies especially to children; but occupational therapy, various educational measures, and family psychiatric case work attempt the same thing. Mere removal of exciting causes is not a complete therapy. While the individual might achieve a more relaxed physiological state under such conditions, re-education is not something which can be *done to* the patient. Environmental therapy aims at the learning of effective adjustment to normal demands, and this requires a motivated subject. If pressures are first relieved, the main function will be to bring the patient within a range of discriminatory reaction wherein reorientation and redefinition of goals may be achieved. It is common practice in many sanitariums to discourage patients against talking over their symptoms with each other. The neurotic likes to revive his physical tensions because of their protective function, and the extinction

²⁶ F. Allen, *Psychotherapy in Children*, Norton, 1942.

²⁷ C. Rogers, *Counseling and Psychotherapy*, Houghton Mifflin, 1942.

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of this practice aids in the building up of new responses. Environmental therapy, properly directed, may thus either supplement or substitute for expression therapy in the reorientation of equilibratory patterns of homeostatic adjustment.

Physiotherapy. We include here the various methods for securing temporary reduction of tension or release of aroused excitation, as well as habitual practices that work off the "head" of the pressure. If motor automatisms (127), swearing (92, 109), gum chewing, or "progressive relaxation" (10, 94) aid lasting reorientation and redirection of homeostatic balance, they do so indirectly. These and other practices such as massage, hydrotherapy, and the taking of drugs do not get rid of exciting causes; but they often work a temporary reduction in the general excitation background. Such methods direct the concentration of the patient on a new task, so that both directly and indirectly the self-maintaining tensions of the neurotic behavior pattern are reduced. Certainly in the calmer physiological state (less residual tension) the patient's anxieties will be less intense and he may be able to face his conflict and make a new reaction. In mental hospitals, physiotherapy is sometimes used on psychotics with the hope that a "prior calming" down will bring them to a state where the psychiatrist can attempt some form of expressive psychotherapy. Current evidence (87) would suggest that with many anxiety-ridden patients it is better simply to tell them to relax than to attempt to instruct them in elaborate relaxation procedures.

Shock Therapy. We come finally to the shock therapies, whose use constitutes one of the most telling supports of homeostatic doctrine. In the psychotic patient, we have a case of total homeostatic adjustment that has become very

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rigid and deeply ingrained. The capacity for cerebral management has been lost outside of narrowly defined limits. Expressive and environmental therapies are utterly inappropriate and no reorientation or release can be established with these methods. If anything is to be done, it will have to be through some drastic shock that forces the patient, momentarily at least, out of the patterned physiological complacency in which his system has been so rigidly set. Ordinary external stimuli will not produce displacement, and so recourse is taken to the physiological "shock" effects induced by abnormally high or low temperature, elevating or depressing drugs and hormones, particularly metrazol and insulin injections. No paranoid belief in one's identity with Napoleon is of aid in equilibrating such profound disturbances in bodily economy. If the condition does not kill the patient by forcing basic homeostatic processes beyond their margin of safety, total homeostasis may be "shocked out" of fixity by its sheer inadequacy to meet the crisis. In readjustment to physiological shock, the way is also made open for reorientation at the behavioral level.²⁸ Such reorientation of homeostatic adjustment is the indirect consequent of a displacement which shows up the inadequacy of a former adjustment pattern. This differs from expressive, environmental, and physiotherapy, all of which seeks in one way or another to relieve existing tensions rather than to create new ones.

There is limited evidence that the principle of shock therapy—necessarily applied to the homeostated psychotic—is applicable under certain conditions to milder cases. The *Stress Interview* technique, which was described in the last chapter, is known to have caused some helpful re-

²⁸ G. W. Kisker and G. W. Knox, "Shock therapy as a psychobiological problem," in *20th Century Psychology*, Philosophical Library, 1946.

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orientations of reaction tendencies. Shocked into a realization of their inadequacies, several normal subjects who participated in these experiments later reported that the stress had led to a self-initiated program of improvement. Our own experience does not include neurotic cases, but the private communication of one psychiatrist is illuminative. A haughty and pampered woman was referred to him, very much against her will. After some time spent in getting nowhere, he suddenly slapped her face. In the torrent of abuse which followed this shock, the repressed material began to pour forth and expressive therapy was instituted.

When to shock, when to sooth, and when to be neutral is a matter on which therapists have as yet reached no common agreement. The answer presumably lies in improved methods of diagnosing behavior disorder. Many cures have been reported for all the methods surveyed, as well as many failures. Some clinicians incline toward use of the same basic therapy on all comers. Others incline to the shotgun attack, using all methods in the hope that one will work. Such a procedure might be eliminated by proper knowledge of individual differences.

Behavioral Energetics and Therapy Our preliminary analysis of human reaction systems has opened the possibility for diagnosis and therapy based on differences in behavioral energetics. Each organism may be regarded as a developed energy structure. If the basic pattern of the interacting factors could be ascertained by tests of homeostatic reaction, we would be a long ways toward a rational therapy. In the foregoing sections we have shown how the homeostatic context fits the four types of therapy better than does a mentalistic orientation. It remains to indicate how physiological tests of behavioral energetics might aid in the selection of the proper therapy for the individual case.

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Here we must go far beyond observed data and advance a tentative hypothesis subject to later check. On the assumption that a given energy structure indicates too great (inhibiting) discharge control over aroused energies coupled with high discriminative capacity, some form of expressive therapy may be indicated. The environmental or milieu type of therapy might be used with profit on energy structures requiring primarily a reduction of aroused energies. Physiotherapy might be indicated for systems which required either raising or lowering the basic energy level and shock therapy for a deeply rooted and very rigidly limited reaction-structure that cannot be reoriented by less drastic types of displacement. It is encouraging to see preliminary attempts (86, 87) made to evaluate various therapies from a physiological base.

The fact that no single therapeutic method has convincingly demonstrated its applicability to all cases is evidence that better choice of treatment is urgently needed. Another fundamental weakness is that present practice takes the patient too late in the development sequence to be of permanent help.

The psychiatrist of today is like a captain called on the bridge after the ship has started to sink. Crucial stress has already weakened the patient and caused his homeostatic adjustment to approach or go beyond the point (optimal reaction range) where high order and specifically adaptive reactions can be made. What is needed is some early indicator of the degree of "loading" a given system can withstand (psychiatric "plimsoll mark") coupled with methods for analyzing the basic maladjustments of energy structure that require correction. Only then can a program of preventative and remedial medicine have a rational base. Much of our mental hygiene movement has shot wide of the

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mark because it deals too exclusively with overt manifestations of early behavior disorder. Rethinking the problem of personality disorder in terms of energy structure should result in a more adequate form of emotional education.²⁹ Whether this will banish the problem of behavior disorder may be questioned, but it can certainly reduce its depth and scope.

Some Final Considerations. This account of the energetics of human behavior ends, quite properly, by raising many more questions than it has solved. The exploratory character of our researches in neuromuscular homeostasis, particularly as they relate to the problem of behavior disorder, is well recognized. The aim has been to provide a systematic setting for dynamic behavior study, a setting in harmony with the macroscopic biology of the constant states whose maintenance are essential for the preservation of organismic identity. We have shown the behavior integrated by the higher nervous centers as contributory to the maintenance of biological constancies, and we have indicated that even behavioral maladjustment is a striving for neuromuscular homeostasis. The time is rapidly approaching when clinicians will no longer be justified in dismissing physiological approaches to psychoses on grounds that "not enough is known." Through the study of neuromuscular homeostasis, organic and functional disorder, body and behavior are inseparably linked. In order to emphasize this connection, a recapitulation appears in order.

Overt behavior is conceived as a means of discharging in a co-ordinated, specifically adaptive fashion bodily energies developed by internal needs and associated frustra-

²⁹ D. A. Prescott, *Emotion and the Educative Process*, American Council on Education, 1938.

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tions, and as functioning to maintain the homeostatic balance of the total organism. In order to preserve essential constancies, the organism must adapt itself to change in the external and internal milieu. It does this by an interplay of fixity and flexibility. When any threat to organismic identity develops, this tends automatically to set into operation a series of behavior mechanisms that counteract the stress and aim to return the organism to equilibrium. Specifically adaptive mechanisms may fail to materialize for one of three reasons: (1) inadequate energy mobilization needed to effect appropriate discharge, (2) blocking of adequate discharge mechanisms and the consequent overflow of aroused tension into less adaptive discharge mechanisms, and (3) development of an abortive discharge mechanism whose physiological equilibrating action is offset by its great fixity, and its nonflexible, nondiscriminatory character in total organismic action.

All modes of response represent the best that the organism is capable of under total existing conditions. Just as the body in its resistance to infectious disease adopts nondisruptive protective reactions as long as possible before resorting to defense reactions that seriously interfere with the patient's normal functioning, so when personal constancy cannot be achieved by limited defections, more profound ones are inevitably adopted. Fundamentally, the *nervously unstable personality* is one that does not adequately discharge aroused excitation in a fashion to give lasting relief and equilibration. The *neurotic* usually presents even greater discrepancies in the ratio of bodily energies mobilized under certain displacing conditions and in the overt reactions adequate for re-equilibration, but his behavior toward many other situations is still specifically adaptive. The *psychotic* on the other hand may achieve

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complete physiological re-equilibration by a bizarre, non-discriminatory reaction, although at the expense of response flexibility and social reality.³⁰

In a conflict situation, any response that will reduce tension tends to be tried. Only when there is a powerful inhibition over the most equilibratory discharge will less satisfactory modes of response be fixated. Tics and motor automatisms, useful in reducing tension in one situation, then become self-perpetuating and begin to appear in other situations (127). Bona fide diseases and injuries are even seized upon and perfected as tension-reducing devices. It is conceivable that the value of an illness in reducing a family tension situation might produce an organic condition that would even keep a bone from knitting. As behavior becomes more and more disorganized, and less and less adaptive to the total aspects of total adjustment, the individual is well launched toward a neurosis.

What can be done to arrest such a progression? The answer apparently lies in the phrase, "training in the control and channelizing of nervous discharge." It is the tendency of our society to generate in the individual more energy than he can naturally expend. Synthetic demands arouse the organism to high "aspiration levels" but do not provide easily attained avenues through achievement. Until an aroused social consciousness legislates against the practice, our advertising copy writers will continue to implant cer-

³⁰ A certain similarity might be seen between this account and the psychoanalytical conceptions developed by Fenichel (*Int. Z. Psychoanal.*, 33, 39, 1937). He holds that all neuroses are the motor discharge of a dammed-up impulsive energy. Psychoneurosis is brought about by lessened opportunity for discharge because of dread of the outer world and inhibitions of the superego. Traumatic neuroses are interpreted as due to the sudden overwhelming accumulations of energy which break through inhibition to affect a psychotic syndrome.

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tain needs and desires and then frustrate their realization. Unless we are early conditioned to see them for what they are, we shall be taught by the movies and books to be infinitely ambitious, to want more and more that we do not actually need. People should, of course, be encouraged to embark upon worth-while goals and to work as if they were obtainable. If insurmountable frustration develops, they must appreciate the satisfactions of more moderate accomplishments, working off the remaining tensions in substitute channels of discharge.

A man may use skeletal, verbomotor, and ideomotor (phantasy) mechanisms to release aroused nervous tensions. He can develop hobbies as well as work adjustments. By attempting a personal synthesis of various discharge outlets one can be better prepared to use specifically appropriate means of tension release. While skeletal action constitutes a first-line mechanism for relief, it also carries the greatest external risk (i.e., to knock down an enemy may create more problems than it solves). Phantasy discharge on the other hand will involve no external risk, but may be either a failure or a too successful (from a personal standpoint) form of relief. Speech has been called the middle ground. That is why talking out one's troubles is such good general therapy. The well-adjusted person, with knowledge of this fact, will work out many compromises of verbal discharge in the course of his life. He will also strive for a number of interests and reaction tendencies, since variety as well as type of discharge helps one to keep sane.³¹

In the development of society and interdependent life, indirect methods of obtaining food, protection from dan-

³¹ A practical guide to the principles of effective response discharge will be found in G. L. Freeman and E. Stern, *Mastering Your Nerves*, Harper, 1946.

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ger, and sexual gratification tend to make the most direct equilibratory discharge relatively impossible. Delay, postponement, and restraint—rather than direct expression—are the rule. Not only does civilized man have less direct release of aroused energy; he has also pyramided upon his primary drives a host of secondary ones with a consequent continued orientation toward these drives. Society bombards man with countless desires, many self-contradictory, some impossible to satisfy, and leaves him in a state of almost perpetual mobilization. Prohibitions, inhibitions, and frustrations limit the channels of discharge. Is it any wonder that neuroses increase as society matures?

Our final analysis of behavior disorder must take an account of the culture in which it appears. It has been pointed out³² that differences in neurosis typical of different cultures may be understood to be conditioned by the amount and quality of conflicting demands within the particular culture. While our society places a premium upon a certain type of aggressiveness, such behavior is considered aberrant in the Zuni culture³³ of the Southwest Indians. The Kwakiutl may be characterized as having grandiose attitudes, ideas, and practices which we would regard as paranoid but which for them are standardized into accepted patterns. A reviewer³⁴ of this and related evidence emphasizes that mechanisms for discharged biological tension are developed to fit in with the culture patterns of the group. In the Dobus of New Guinea, for instance, most behavior is dominated by an amazing para-

³² K. Horney, "Culture and neuroses," *Amer. J. Sociol. Rev.*, 1, 220–270, 1936.

³³ R. Benedick, "Patterns of culture; Anthropology and the abnormal," *J. Gen. Psychol.*, 10, 51–82, 1934.

³⁴ K. Young, *Personality and Problems of Adjustment*, Crofts, 1945.

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noidal fear of sorcery. People who run amuck are not outside the pale of this society; but a friendly man of sunny disposition is regarded as crazy because he likes to work and be helpful.

In a culture pattern that definitely prohibits certain discharge mechanisms, particular forms of substitute discharge are likely to be prevalent. For our own culture, it seems that prohibitions over expression of unbridled skeletal discharge (punching a man in the nose when angry, attacking any woman when sexually aroused) or of verbal discharge (talking back to superiors) result in a tendency to shunt aroused energies to the hollow viscera or to the ideomotor level of phantasy discharge. This is reflected by the large increase in organ neurosis in modern society, and by the oft-quoted phrase "most men lead lives of quiet desperation."

Of late, we have heard that it is preferable to err on the side of expression than on the side of repression; but to remove inhibitions without positive training in the routing of tension discharge is also to invite chaos. An optimal range of frustration is basic to a vigorous society and a developing individual. Gratification can go too far, and lead to loss of individual and group motivation. One has only to read Suetonius' *The Lives of the Caesars*, to see the deterioration that results when neuromuscular homeostasis is not subjected to training in higher-order discharge control.

We must not forget that although organisms are forever evolving, the process cannot be left to the cosmic rays. Already in possession of highly adaptable neuromuscular systems, men could take their fate in their own hands and construct a rational society for the homeostatic satisfaction of their needs. Why does this remain only a hope? Largely

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because the basic problem—*human energy and its control*—is not yet solved on an individual, let alone a group, level. Until this is done we shall not be able to pass from this “age of unreason”³⁵ to that hoped-for state when “man will be superseded by superman.”³⁶

³⁵ F. Alexander, “The influence of psychological factors upon gastrointestinal disturbances,” *Psychoanal Quart.*, 3, 501–588, 1934.

³⁶ O. L. Reiser, *The Promise of Scientific Humanism*, Oskar Piest, 1940.

The Psychosomatic Relationship

Isomorphism. Kohler and other “gestalt” and “field” theorists subscribe to an isomorphic doctrine of the psychosomatic relationship which stresses point-for-point correspondence between psychic and physiological structures.¹ The apparent strength of this treatment lies in the specificity of its “identity” postulates and in its neutral attitude with regard to the problem of causation. Heretofore the parallelistic position had been only an expressed hope of relation. Biologists made their descriptions in terms of the microscopic action of parts, and in their sphere of mental phenomena the early psychologists attempted to do likewise. But as the structuralist failed to demonstrate concrete physiological correlates for their microscopic attributes of sensation,² introspective description shifted to the macro-

¹ W. Kohler, *Dynamics in Psychology*, Liveright, 1941.

² Attention is called to the growing support for quantitative theory of sensory process. According to Nafe (*Psychol. Rev.*, 1941) “cold,” “warm,” and other somaesthetic qualities are meanings based upon quantitative differences in the pattern of nerve excitation. Growing evidence that the elementary sensory qualities are no exact guide to microscopic physiological qualities is found in other sense fields. Cf. E. G. Boring, *Physical Dimensions of Consciousness*, Appleton-Century, 1933; Stevens and Davis, *Hearing*, Century, 1938. The point is also stressed by G. L. Freeman, *Physiological Psychology*, Van Nostrand, 1948.

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scopic aspects of conscious experience³ and led to a bold extension of parallelistic postulates. Since the macroscopic description of somatic events had been either neglected or found impossible of investigation by existing methods, the suggestion was made that macroscopic descriptions of psychic events might provide a basis for the construction of their isomorphic somatic correlates. In the field of visual perception, at least, this appeared very fruitful. Here external stimulus configurations could be readily manipulated to produce correlative changes in the total phenomenal experience. By assuming analogous field-force relations in physical (stimulus), somatic (cortical), and psychic (phenomenal) realms it was possible to construct provocative macroscopic theories of intervening somatic action by re-writing the phenomenal description of physical terms.

If we are to assume that the description of conscious wholes (products of interacting part-wholes) constitutes a true representation of the macroscopic features of essential somatic correlates, there is no reason why such theory construction should not be encouraged. At least it should make the physiologist aware of the limitations of his microscopic methods of part-analysis. But it may not *substitute* for

³ The term "phenomenology" is used here to refer to any and all systematic investigations of the phenomena of conscious experience. In its original and narrowest sense, phenomenal description would be held to immediate existential events (such as the sensation of red) without reference to their implications (such as the meaning danger). However, modern phenomenal description is now interested in these macroscopic "meaning" properties, rather than in the microscopic sensory attributes. Titchener (*Amer. J. Psychol.*, 11, 1912) recognized the value of microscopic description (introspection) and macroscopic statement of phenomenal meaning (Kundgabe) in the same report; this distinction has been preserved to the present day by Bentley (*The Field of Psychology*, Appleton, 1924) in his method of introspection and his method of commentary. Gestalt psychologists have interest only in the latter.

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those (yet undiscovered) facts of somatic analysis, and Köhler,⁴ much more than his followers, realized this fact. In a very significant closing paragraph to his treatment of the problem he says:

If structurally and functionally the neural counterparts of mental processes are isomorphic with these processes [the reader may ask] why should we speak of two different things? Why not identify the former with the latter or vice versa? My answer could be another question. What advantage, I should say, could be derived from this simplified formulation? It may be that some such moniam will sooner or later appear as the natural view in the field. I am sometimes inclined to think so myself. But at the present time the theoretical situation does not seem ripe for such a step. . . . As to the psychophysical problem, phenomenal observation is one procedure, and the construction of isomorphic correlates, *plus their hoped for demonstration in physiological work*, is an entirely different procedure. So long as isomorphism remains an hypothesis which will have to undergo one empirical test after another, it would merely confuse our own theory if we were to anticipate a positive outcome of all these tests, and to undertake further speculation on such an insecure basis.

If we are to believe the essential unity of the sciences (and this is basic to isomorphic doctrine) then we should expect those persons who are most aware of the macroscopic problem in the psychic field to display a great interest in the search for empirical correlates in the somatic field.

This has a special "requiredness" if one is to construct theories about brain dynamics. Helpful as is a background in physics, it will not substitute for a biological context. It is not the contention that long hours spent in the micro-

⁴ W. Köhler, *Dynamics in Psychology*, Liveright Publishing Corp.

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scopic study of dead nervous tissue will help in the construction of more realistic doctrines of psychophysical relations, though a vigorous materialistic "set" derived from such study would be all to the good; rather it seems that a firsthand knowledge of the subtleties of blood pressure measurement, etc., would give the student of phenomenology an insight into the possibilities of macroscopic biological description to which he is at present quite blind. It is a fact that isomorphic theory of cortical brain dynamics has been stated in such a manner that it could be empirically tested by physiological means, and this absence of test is more a fault of statement than of adequate means of test.⁵ Those who construct isomorphic theories of brain function do not study physiology and are apparently proud of the fact. But can the biologist's study of the human machine so conceal its macroscopic functions that the phenomenologist is the better qualified to describe them? Anyone who has read the works of such great physiologists as Sherrington and Cannon knows that these men are well aware of macroscopic problems. The psychophysiologist is likely to object to the assumption that reports of conscious events constitute a "complete behavioral description."

⁵ Kohler appears to take the brain as an isolable physical system and talks in terms of movements of electrons and biochemical processes going on therein. One may question if biology is yet ready for this step, even in theory. Most biologists are only now getting to the electrical study of brain activity, and the biochemical approach is still to be exploited. Until more results are forthcoming from these types of research, it seems unwise to treat the action of the brain without regard to its composition or to the effect of other bodily activities upon its reactions. In the theory of apparent movement, for instance, how can one test for "cortical short-circuits below the psychophysical level"? Kofka's ingenious isomorphic theory of three-dimensional cortical projection in depth vision is out of line with known facts of spacial disposition in the projection areas. Furthermore, Stratton and Young's experiments on special localization refute the nativism implicit in Kofka's doctrine.

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A sharply drawn distinction between the phenomenological report and the behavioral report would do much to clarify the problem. Phenomenology is the study of conscious awarenesses and uses verbal behavior to "express" these facts of experience. Other forms of behavior than speech (gestures, writing, painting) might be used as phenomenological expressions, and much concomitant behavior such as the circulation of the blood or tensions in the stomach is disregarded in the reports of the phenomenological consciousness. A *complete* behavioral report would take into account all the motor activities of the organism, verbal or otherwise. The use of verbal behavior as an index of *complete description* is permissible only if one assumes (1) that it is a complete expression of the phenomenal consciousness and (2) that phenomenal consciousness is synonymous with all that is significant in total behavior. That neither of these assumptions is true is shown by the need for supplementing the verbal report with other behavioral indices (such as blood pressure readings) in the detection of guilt. The phrase "conscious behavior" appears to have no meaning except "behavior with conscious accompaniments." The behavior of organisms is actually composed of the interactions of nerves, muscles, and glands. Consciousness, along with nest building, maze running, and perversions, is one of their products. The muscles and glands are the structures that react to stimulation and their behavior can be measured quantitatively. In the sense of being a determinant of reaction, consciousness does not behave. If one wishes to speak of speech behavior (a motor process) as having conscious concomitants there is no objection; but students of the phenomenal consciousness should be the first to admit that verbal behavior is an inadequate expression of all that is needed to explain the

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organism's conduct—witness for example, the “unconscious” of Freudian theory.⁶

The most cogent criticism of isomorphism appears to have been stated by Köhler⁷ himself. “I have sometimes heard,” he says, “that the theory of psychophysical isomorphism is a verbal rather than a substantial achievement. It is easy, thus some seem to feel, to abstract from psychological facts their structural characteristics, and then describe such psychological structures twice, first in psychological terms, then once more in language which has a more physiological sound. It is obviously the import of this criticism that the theory does not really contain statements about both physical and psychological data; that actually there is only one single set of factual statements which by the use of two different sets of expressions assumes a dual appearance.”

No amount of verbiage with which Kohler follows these statements appears to alter their basic truth. Although one may agree with the contention that “macroscopic physical states rather than microscopic events are the correlates of phenomenal contexts,” it does not follow that the latter type of examination creates facts of physiological context. Isomorphism produces *theories of alleged physiological fact*, and as yet it has failed to attempt the kind of em-

⁶ The fact that so much total behavior is unaccompanied by consciousness undermines a psychic determinism and strengthens the alternative position of somatic determinism. E. B. Holt (*Animal Drive and the Learning Process*, Holt, 1931, p. 8) has an interesting hypothesis that “mental phenomena are found only in an organism when stored up energy is released, by stimulation of sense organ, to produce muscular contraction.” Activity in sensory nerves and muscular contraction means catabolism and thus may be conscious. The processes of nutrition, growth, and repair of tissues are anabolic and, therefore, according to Holt, elude introspection.

⁷ W. Kohler, *The Place of Value in a World of Fact*, Liveright, 1940; for a criticism similar to that voiced above cf. E. B. Holt, *op. cit.*, p. 4.

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pirical verification that has meaning to physiology. Who is to do the physiological experimentation? Certainly not the students of microscopic behavioral analysis who are supposedly unaware of the problem and whose theories these are not. The person who constructs an isomorphic theory accomplishes nothing by throwing the problem into the laps of the physiologists, who also are unaware of the matter.

As a student of biological reaction dynamics, the author is inclined to suspect that psychic events are as ineffective a guide to knowledge of somatic events as they are inaccurate signs of the physical stimulus. Gestalt psychologists have inveighed against the constancy hypothesis as applied to stimulus-experience relationships. The isomorphic doctrine, however, is an unwritten relapse into the constancy error. If the shifts in physical and phenomenal events are not exactly co-variable, it seems that isomorphic doctrine might well turn its attention to a quantitative investigation of the variance in cognate physical and physiological processes, rather than content itself in a mere rewriting of phenomenal data so that it will have a physiological sound. What value comes from postulating "traces in the brain field" to explain the time error in successive comparison judgments if these traces cannot be isolated and measured independent of their products?

One further criticism of isomorphic doctrine may be advanced, namely, its preoccupation with the alleged *cortical* correlates of phenomenal events. Now there is a presumptive reason that cortical processes are somehow related to consciousness; but it is in no wise proved that these structures are any more essential to consciousness than are other bodily contributors to behavior, such as the muscles and glands. Most objective psychologists have argued

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that there must either be passage of nervous current from affector to effector or else backlash from effector to brain in order to produce conscious phenomena. Their researches have certainly shown that peripheral muscular processes are inextricably bound up with central (cortical) events. Gestalt psychologists, by their frequent neglect of such peripheral components of action, are thus failing to recognize the unity of the organism.

The author finds the *active* view of mind, so characteristic of American psychology since the time of James, rather lacking in the psychology of gestalt. There is too much of the old *tabula-rasa* passivity latent in the appeal to isomorphic correlates of phenomenal events, too great a disregard of motor adjustment (implicit or explicit behavior), except as overflow phenomena—mere reverberations of allegedly more essential processes in the brain field. It is agreed that the biological processes underlying phenomenal events must be treated macroscopically. Beyond this, however, it would appear best to consider the behavior of the organism-as-a-whole—the interaction of all its bodily parts—rather than confine physiological inferences regarding consciousness to one part alone, the central brain cortex.

Somatic Determinism. In the exposition of the psychosomatic relationship, the author regards attainment of a truly biological context as the primary need. The only workable approach to this relationship appears to be a rigorous somatic determinism in which mental events are regarded as epiphenomenal to more basic somatic events.

In a given energy system where various manifestations of a change appear concurrently it is pertinent to inquire if any one of these manifestations is more fundamental and the necessary condition of other manifestations. Consider

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the burning of a piece of coal; the essential conditions are a certain temperature, a certain chemical structure, and a certain physical state. When the interaction of these essential properties is sufficiently rapid, the coal glows and bursts into flame; when the rate of energy transformation is slower, the coal has the appearance of gray and lifeless ash, and it is only by touching the object that we are made aware of the fact that the same burning process is still going on. The glow described in the first instance is a manifestation of energy transformation; its presence or absence gives a rough idea of the rate of the essential oxidative processes. No one would claim, however, that the glow was a determinant of the oxidative processes. In other words, some manifestations of energy transformation may be considered as epiphenomenal or secondary, determined by the interaction of other and more primary manifestations. Glow does not make the coal burn, nor is it an essential covariable. The application of this analogy to the organismic energy system has significant implication for the relationship between mental and bodily processes. For here degrees of consciousness are seen as variations in "glow," produced by the rate of interaction of basic somatic energy transformations. It is a product of these reactions, and while just as "real" as any other aspect of organismic energy transformation is an instance of one-way causation.

The theory of somatic determinism is to be contrasted with the psychosomatic solution of gestalt theory and psychoanalysis and with the materialistic monism of Watsonian behaviorism. In psychosomatic solutions conscious events often serve, by implication at least, to represent forces which affect the body; and in Watsonian behaviorism consciousness is ruled out of any consideration whatever by denying that it is at all pertinent to psychological study.

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One can hold that consciousness is an epiphenomenon—a mere shadow of underlying physiological processes—and, if he chooses, still use those shadows as rough indicators of changes in more basic phenomena which must be studied later with more refined methods. The astrophysicist who is unable to estimate the size of a planet star directly can avail himself of the shadow that it casts. The chemist who has no more refined means of estimating the thermal point at which several elements combine to form a new compound can use the cognate change in glow—an epiphenomenon—to some advantage. Similarly, there is no reason why the report of phenomenal consciousness cannot be used as a rough index of behavioral change. Some psychologists will undoubtedly prefer to engage in such study exclusively, but the pretensions of constructing rigorous behavior theory on such data is denied by somatic determinism.

The chief reason for such denial appears in the shadow analogy. If this epiphenomenon moves, and we have no other check, we may not tell which of two things happened to the basic phenomenon—whether the light source changed or the position of the object upon which it is cast. We have no assurance that the experience of “blue” is the same thing physiologically in all individuals. Furthermore, the same conscious meaning may often be produced by different physiological processes. Unless one is primarily interested in theory of knowledge or other epistemological problems, he can accept the phenomenal report with reservations and then go on to check how the individual behaved in terms of more objective measures.

The question is always raised, how does the brain (or the bodily processes) produce its epiphenomenon-consciousness. It may be that such structures generate consciousness at certain levels of physiological activity, just

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as a piano produces music when the keys are pressed hard enough or a dynamo generates glow in an electric lamp when run fast enough. In the dynamo a slow revolution—corresponding to a slow metabolic rate—may heat up the lamp filament without producing enough current to cause it to glow; if the rate of dynamo action is too fast, this will burn out the filament. Similarly, consciousness is conceived to accompany a limited range of bodily action, and if any scientific problem remains it appears that it should be set to gauge the physiological range over which the epiphenomenon occurs. Detailed analysis of the experimental evidence on motor accompaniments of consciousness and vice versa appeared in the first chapter of this book. It is recognized, of course, that such results do not prove the causative implications of somatic determinism. The majority of psychologists will probably regard this matter beyond the range of scientific attack.

Organismic Biology. The foregoing discussion of somatic determinism has indicated that certain implications in mechanistic behavior doctrine are at odds with the dynamic constructs of organismic biology. This discrepancy is frequently used by writers on psychodynamic theory to confound the behavioristically minded psychologist and to claim for themselves a closer affinity with organismic biology. It is the purpose of this final section to indicate that behavior theory is not necessarily atomistic and that many psychodynamic accounts of the psychosomatic relationship are not good organismic biology.

We have already seen the need for adopting the macroscopic view of organismic biology instead of the more traditional one of atomistic mechanism. It must not be assumed, however, that the organismic doctrine is synonymous with "field theory," psychoanalysis, and other psychodynamic

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treatments; these are but varieties of organismic theory involving implicit assumptions of a psychosome—a mind in a body. Even with mind left out of any formal consideration, biology has its critical organismic philosophy, and to this doctrine rather than to atomistic mechanism the view of somatic determinism must now be oriented.

The atomistic philosophy is historically the older doctrine in biology. It arose from a strict application of inductive scientific reasoning to the behavior of living material. It led to a description and classification of bodily parts and to a study of locally determined function. As applied to total behavior study, it tended to associate specific stimulus excitations with specific responses through the medium of restricted and rather isolated reflex arcs. The dynamic interplay of these part reactions was missed almost entirely by this approach, and responses were classified either in terms of their overt similarities, of similar stimuli which elicited them, or of results produced. That there was an untouched problem of organization was seldom denied by the atomistic mechanist; but this problem was usually passed back to the geneticist and from him to the theoretician without any adequate solution. The one positive thing that the mechanist did was to affirm that no *élan vital* did the organizing and directing of the microscopically dissected machine. But in denying the capacities of the engineer to the "soul" or "free will," the mechanist usually fell back upon the directing power of the stimulus. This tended to make of man an automaton at the full mercies of external promptings—simply a jumping jack behaving like a complicated slot machine.

In contradistinction to this position, an organismic biology insists on taking a larger view of the functioning totality. It sees man not so much as a machine of isolable

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parts, but as an energy system. Its primary concern is with properties of the total system, which it recognizes as differing from those of its constituent parts. It proceeds by hypothetico-deductive methods to study how the interaction of parts produce changes in the behavior of the whole.⁸ Its fundamental construct is *energy*. This is never found in a free or nascent state, but always exists in organized systems. An atom is a system of energy and so is a galaxy. Man is a system of energy standing midway between these minute and cosmic patterns of energy. His behavior follows laws that are in harmony with those of other energy systems. In this sense he may be regarded as a *microcosm*, a system combining all the organizational principles of the universe. The energetics of man's behavior are relatively more complex than those of the atoms; but they are much less so than those of the galaxies, the behavior of which often appears unpredictable for want of sufficient insight into the part-influences which are operative.

⁸ This description of organismic biology is at variance with J. F. Brown's interpretation (*Psychology of the Social Order*, McGraw-Hill, 1931, p. 26) which more or less ignores interrelations of mechanistically derived parts. It is precisely a neglect of this problem by atomistic mechanists that has permitted Brown's statement of the whole as "more than the sum of its parts" to go unchallenged. Brown also states that mechanism implies an intelligent external creator, as with the automobile, while organismic doctrine alone can account for man as evolving independently of any inventor. Who can say? It appears that we take an organismic view of even the automobile when we become interested in its total functional properties and that these can be studied by putting on an automatic governor and setting the wheels to run in a prescribed path. There is nothing mystical about a whole machine which cannot be assayed by proper study of the interacting parts, speed (a total property) resides in no particular part, but accrues to the whole through part-interactions. Simply pointing out that a machine has speed is not much of an achievement. Nor is there any special virtue in referring to such pointings as "organismic." In this exercise the essential problem of how parts function in wholes is all but lost.

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Organismic biology constitutes those postulates and constructs which regard the total man as an energy system. It recognizes that, as an energy system, man has his bodily parts—the nerves, muscles, and glands. These correspond by analogy to the positive and negative charges whose interaction is responsible for the atoms' total behavior, or to the planets whose interactive forces maintain the solar system. "Mind" is not a part, but an aspect of total action, and any use of the term psychosome properly implies no reference to an outmoded mind-body interactionism.

In other fields of scientific endeavor, knowledge of parts has tended to go along with understanding of dynamic wholes. The same is true in biology. Survey of static parts, together with study of their functions in isolation, has given way to study of interacting parts within a larger functional total. We have, for example, passed from consideration of one gland alone to the problem of endocrine interaction. Only those who would exalt the priority of the whole and treat it as existing independent of parts will continue to see the general mechanistic approach as opposed to organismic doctrine.

There is a close relationship between the biologist's general orientation and his method of gathering scientific data. A nineteenth century biologist, working on enumeration of parts, was proud of his empiricism and inductive reasoning. The hypothetico-deductive approach, which is becoming more common in twentieth century biology, starts with a "hunch" of a relationship between previously enumerated bodily parts, proceeds to formulate a working hypothesis, and then finds methods to measure the alleged operation empirically. The methods and constructs of organismic biology are thus seen to build to a considerable degree upon the data derived from the earlier atomistic approach. As

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they tend to substitute hypothetico-deductive methods for straight induction and to deal with larger totals, mechanists are simply becoming "dynamic" mechanists.

There is nothing mystical in the term "dynamic" and no reason why its association with organismic biology should imply something extramechanical or essentially psychic. It is sometimes held (see Brown ⁹) that organismic biology is not committed to the ultimate reduction of its total dynamic properties to physical chemical principles. But a little careful reading of the organismic experiments of Child and Osterhout offers convincing proof that such research proceeds in exactly this direction. To assume that organismic biology will develop extramechanistic principles is to assert that organismic biology is vitalistic. The shift from enumeration of part-mechanisms to the study of total reaction dynamics is one of the outstanding growths in sophistication of twentieth century biology. Any attempt, however, to neglect the mechanistic base of operations and substitute gross total descriptions of the psychosome can only result in throwing psychology offside the line of scientific development. An organismic psychology that denies the interacting mechanisms approach to the study of total properties inadvertently enlists with the forces of vitalism.

⁹ *Op. cit.*, pp. 29-30.

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